THE RÖNTGEN RAYS IN MEDICAL WORK.

WALSH.

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THE RÖNTGEN RAYS IN MEDICAL WORK.


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THE RÖNTGEN RAYS IN MEDICAL WORK.

BY

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With an Introductory Section

UPON

ELECTRICAL APPARATUS AND METHODS.

BY

J. E. GREENHILL.

Φάος κάλλιστον τῶν προτέρων.

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PREFACE.

Since the famous discovery announced by Professor Röntgen at the end of the year 1895, a new science has sprung into being. This branch of knowledge, although still in its early and undeveloped stages, has found a special application in medical work.

In this little volume the aim has been to deal with the present practical scope of the Röntgen rays so far as physicians and surgeons are concerned. An attempt has been made to treat the matter systematically, and to point out limitations and possibilities, as well as to record actual achievements. In this endeavour the author has received invaluable help from Mr. J. E. Greenhill, who has also kindly written an introductory part dealing with electrical methods and apparatus. He is also indebted to Messrs. Barwell, Mackenzie Davidson, Lynn Thomas, Professor Waymouth Reid, and many others, for the use of Röntgen photographs and of notes of cases. Where all is new it is by no means easy to decide what is likely to prove ultimately true; but the task of selection has been guided by a constant reference to the everyday conditions of medical practice.

D. W.

The Temple, London, E.C.
Sept. 1st, 1897.

CONTENTS.

APPENDIX.

LIST OF ILLUSTRATIONS.

THE RÖNTGEN RAYS IN MEDICAL WORK.

INTRODUCTORY.

THE RÖNTGEN RAYS IN MEDICINE AND SURGERY.

In December, 1895, Professor Röntgen announced his since famous discovery to the Physico-Medical Society of Würzburg. On that occasion he described certain rays which, themselves invisible, were capable of penetrating many substances opaque to ordinary light. Like numerous other scientific advances, the starting-point of his researches was due to the happy chance of an accidental observation. While making experiments with what is known as a Crookes' tube—that is to say, a glass tube exhausted of air and rendered luminous by the passage of an electric current through its vacuum—he noticed that photographic sensitive paper was darkened. This result the Professor obtained even when the luminous tube was wrapped in a black cardboard cover. He further observed that under similar conditions certain substances, such as barium-platino-cyanide, were rendered phosphorescent. The 'rays' given off by the electrified tube he found to have the power of penetrating various bodies in differing degrees—roughly speaking, in inverse proportion to their thickness and to their density. Thus, bismuth, which has a high atomic weight, offered an extreme resistance to the passage of the rays, which he named the x, or unknown, rays. He found that, in addition to the properties already mentioned, the rays were neither reflected, deflected by a magnet, nor refracted by prisms and other media of ordinary refraction. On the peculiar powers of penetration, of exciting phosphorescence, and of acting upon sensitive photo-

graphic plates, the new art of Röntgen ray diagnosis has been founded.

The exact position of the average medical man towards the Röntgen ray process may be here briefly defined. In the majority of instances he will most likely place his patient in the hands of an expert operator, just as he would apply to a photographer for a photograph, or to a colour artist for a painting. Indeed, it would be out of the question for the busy practitioner to attempt to take his own skiagrams and to develop his own plates, any more than it would be possible for him to undertake complicated bacteriological or chemical examinations. Here and there it is true that an exceptionally energetic surgeon may find it possible to use the fluorescent screen daily in his consulting-room. For prolonged and tedious examinations, however, and for obtaining permanent pictures, the practitioner will naturally have recourse to the professional skiagrapher. Where the latter is not a medical man, little information can be expected beyond the actual surface features of the printed record prepared by him. Where he is a trained medical man, on the other hand, from his knowledge of the facts of anatomy, of surgery, of pathology, and of other branches of medicine, he will be able to furnish a skilled reading of the skiagraphic record, whether of the screen or of the negative. In other words, the interpretation of Röntgen-ray results requires not only practice, but also the knowledge of many cöordinate facts.

Should the medical man desire to operate for himself, he can soon learn sufficient to enable him to work the apparatus both with intelligence and with safety. Dealing with this point, Dr. Richardson,* of Boston, says, pithily enough, that he himself knows nothing about photography, nothing about electricity, and but little of physics. Notwithstanding these drawbacks, however, he has applied the *x*-ray method of examination for many months as a matter of daily routine practice. To quote his own words, his knowledge of the subject extends to 'just enough of the principles involved to place the patient, the tube and the plate in a proper position, and to turn on the current.'

With a good Röntgen apparatus, then, and a skilled workman somewhere within easy reach in case of breakdown, any medical

* *Boston Med. News*, December 19, 1896.

man may teach himself how to use the fluorescent screen and to expose the sensitive plates. The latter can be sent to a photographer to be developed and printed from. It will be advisable, however, for the operator to have some knowledge of the principles involved. In order to present him with a brief outline sketch, the main facts will be dealt with under the headings of (1) 'The Sources of Electricity,' (2) 'The Induction Coil,' (3) 'The Crookes' Tube,' (4) 'The Exhaust Pump,' (5) 'The Fluorescent Screen,' (6) 'Photography,' (7) 'Stands and other Accessories,' (8) 'Practical Application,' (9) 'Theory.'

PART I.

ELECTRICAL APPARATUS AND METHODS.

By J. E. GREENHILL.

I. SOURCES OF ELECTRICITY.

Batteries.

There are several well-known primary batteries which give a steady current sufficient for the longest Röntgen-ray exposure. From four to six cells are required, according to the kind of battery selected. Of the older forms, the Grove is one of the best, though perhaps hardly the most convenient. It consists of a vessel partly filled with dilute sulphuric acid—one of acid to eight of water; a cylinder of zinc open at both ends; a porous vessel, filled with nitric acid, fitting freely inside the zinc cylinder; and a sheet of platinum placed inside the porous vessel. A binding screw must be attached to the zinc, and one to the platinum. If platinum be too costly, carbon may be substituted, when the cell is known as a Bunsen.

The bichromate battery, of which there are various kinds, is more portable, although its current is not quite so trustworthy. It consists of a vessel filled with seven-eighths of saturated solution of bichromate of potash, and one-eighth sulphuric acid. In this fluid are immersed a plate of zinc and one or two plates of carbon. There should be some means of lifting the zinc, or zinc and carbon, from the solution, when the battery is not in use. The bottle form has a closely-fitting cap, to which are attached the carbon and zinc, with an arrangement for drawing the latter out of the liquid. It is portable and convenient, and may be

used with confidence when the current is not required for more than half an hour at a time.

The modern forms of the primary battery are too numerous to describe here in detail. Each inventor claims for his own some special advantage. Whatever kind be selected by the operator, it ought to give a steady uniform current for at least an hour. The rate of the flow of the current generally required is not less than 10 ampères, at a pressure of 10 volts.

A more convenient battery is that known as the secondary, but,

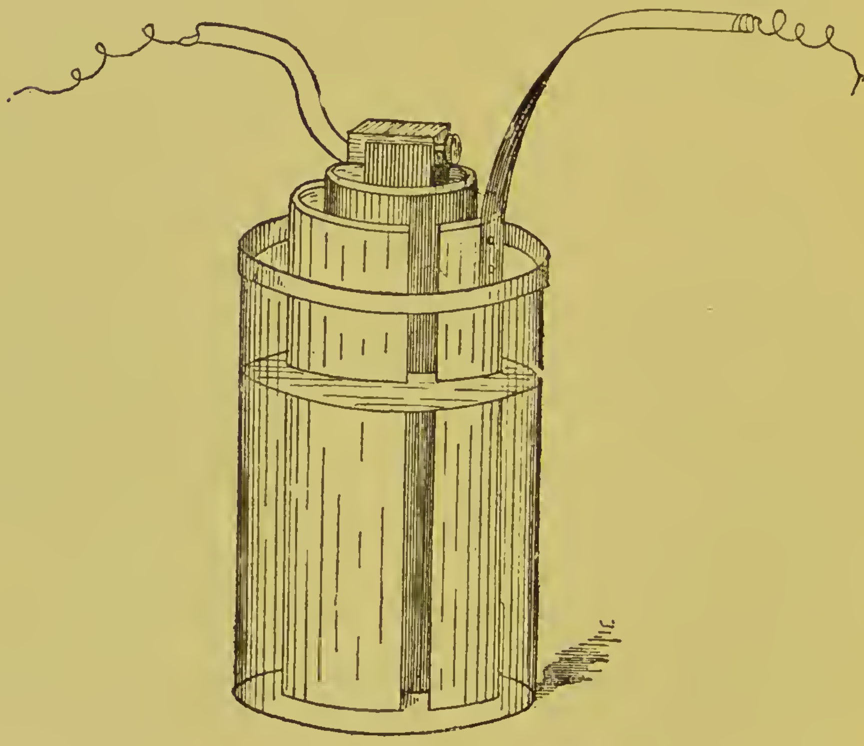


FIG. 2.—GROVE CELL.

unfortunately, it is available only where there are means of recharging at hand. For laboratory work the Electrical Power Storage and the Eppstein accumulators are both good. Five to six cells will be required, from 30 to 300 ampère hours each, according to the demand likely to be made on them. They will give about half the number (15 to 150) working hours; that is to say, the battery could be run at its full

strength for the periods of time last mentioned. It will be necessary to have a second set, or some other source of electricity available while the first set is being recharged. As usually

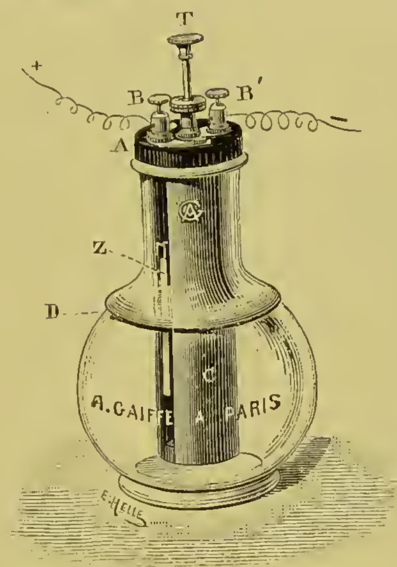


FIG. 3.—BICHROMATE CELL.

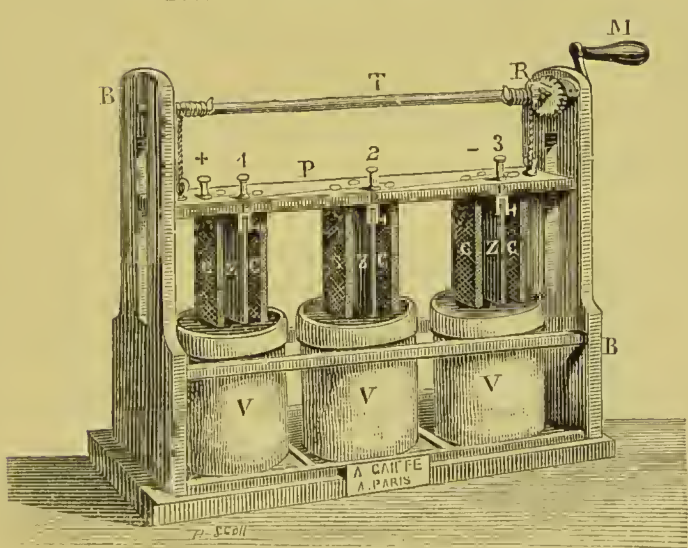


FIG. 4.—BICHROMATE BATTERY.

made, these secondary batteries are heavy and cumbersome. To meet this objection, a small case has been devised for the writer by Messrs. Peto and Radford (Fig. 6). It contains

six cells giving thirty ampère hours at 12 volts pressure. It occupies about a cubic foot only, and so is convenient for

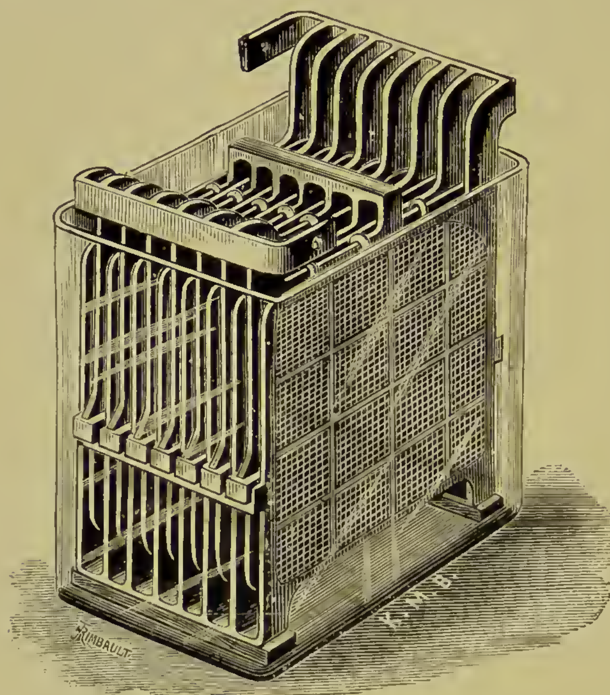


FIG. 5.—SECONDARY CELL.

cases in which the operator must take his apparatus to the patient's house. It should be kept charged by means of the

FIG. 6.—SECONDARY BATTERY.

large cells in the laboratory, so that it may always be ready for use.

A voltmeter and an ammeter are useful in determining if the cells are well charged. The former instrument consists of a bobbin of fine insulated wire, the ends of which are soldered to two binding screws on the outside of the case. In front of the bobbin is a magnetic needle, pivoted so as to move freely upon its axis. This instrument indicates in volts the pressure of the flow of the electric current. The ammeter is similar in construction, with the exception that the bobbin is made of a much larger wire. It indicates in ampères the rate of the flow of the electric current. Behind one end of the magnetic needle of each instrument is a scale, indicating in volts or ampères the current that can be registered by the instrument. Messrs. Newton and Son have arranged the two instruments one above the other on the same stand for Röntgen ray work (Fig. 7).

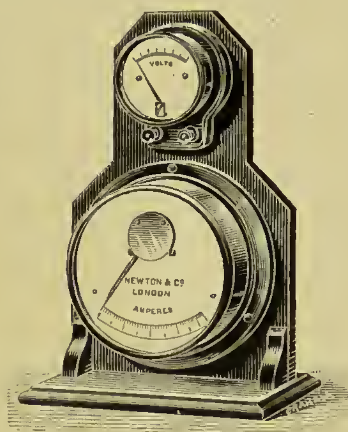


FIG. 7.—VOLTMETER AND AMMETER.

Each cell, whatever its size, when fully charged should indicate on the voltmeter about 2. Directly it falls below 1·9, the cell should be recharged. If an ammeter is used, the wires from the cell should be firmly connected to the instrument. If the meter remains steady at any fair number of ampères, it is still well charged; but if there is a rapid, or even steady, fall, the cell requires recharging. It is never advisable either to discharge the cell altogether or to leave it uncharged, even if not in use. To recharge, a steady current of from 20 to 30 ampères in proportion to the size of the cell at about 2·5 volts' pressure is required for each cell.

In the Grove cell the platinum is the positive (+), and the zinc the negative (–). In the Bunsen the carbon is the positive. In the secondary cell the positive is indicated by +, and the negative by –. Unless care be taken its acid may be spilt in transit. It should be filled slightly over the top of the plates with water (seven parts) and pure sulphuric acid (one part). Whatever the form of the cell, the – of the first cell should be

connected to the + of the second, and so on, leaving the first + and the last – for connecting with the coil.

The third method of obtaining the electric current is limited to those having access to a dynamo through a public or private supply. This is rarely sent into the house at a lower voltage than 100. In order to reduce it to the necessary pressure—10 or 12 volts —a resistance coil must be placed in the circuit between the

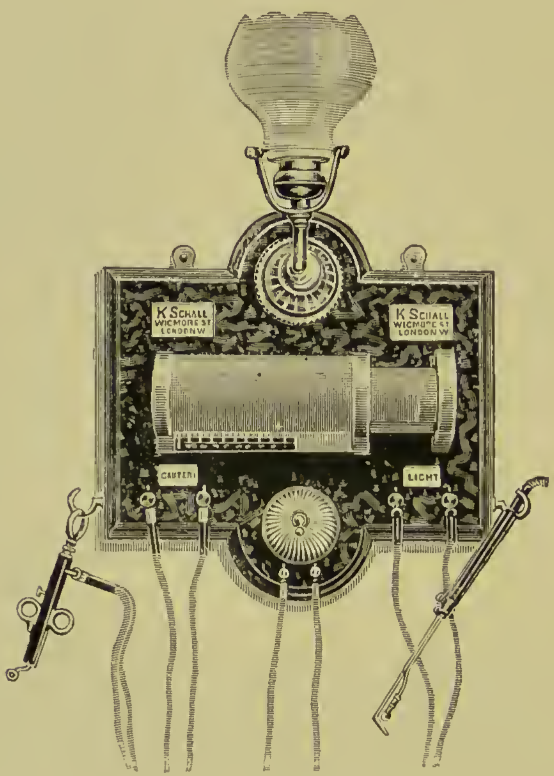


FIG. 8.—TRANSFORMER.

source of supply and the induction coil, if the current be a continuous one, and the wires should be attached to the ordinary terminals on the coil; but if it be an alternating current a transformer must be used, and two special terminals are fixed on the coil to receive the current. In that case the contact break will not be required, and the wires connecting the condenser to the primary should be withdrawn. Speaking generally, this source of electricity has many advantages. It is absolutely

necessary, however, for anyone wishing to avail himself of the electric mains to consult a skilled electrical engineer.

The coil and battery may be dispensed with where a large (about 20 inches) induction machine of the Holtz or Wimshurst pattern is available. But the disadvantages of this method are serious. For instance, the current is not always readily induced, its direction is not certain, and, unless some mechanical means be used for rotating the plates, its strength fluctuates considerably.

Batteries may be coupled up either for pressure (voltage) or

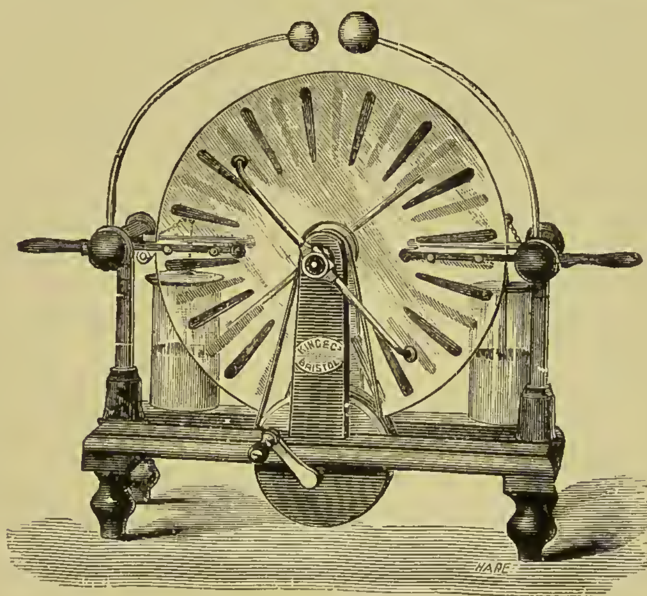


Fig. 9.—Wimshurst Induction Machine.

for quantity (ampèrage). In the former case, the negative (−) pole of the first cell is connected to the positive (+) of the second, and so on; and the current is obtained from the first positive and the last negative. The cells are then said to be in *series*, and will give a current in volts equal to that of one cell multiplied by the total number of cells, and in ampères that of one cell only. In other words, this method of coupling yields the voltage of the whole series, and the ampèrage of a single cell.

In the latter case—that is to say, when coupled for quantity—all the positives are connected to one wire and all the negatives to another; the cells are said to be in *parallel*, and will give a

current in volts equal to that of one cell only, and in ampères that of one cell multiplied by the total number of cells.

Sometimes it is desirable to combine the two methods. Sup-

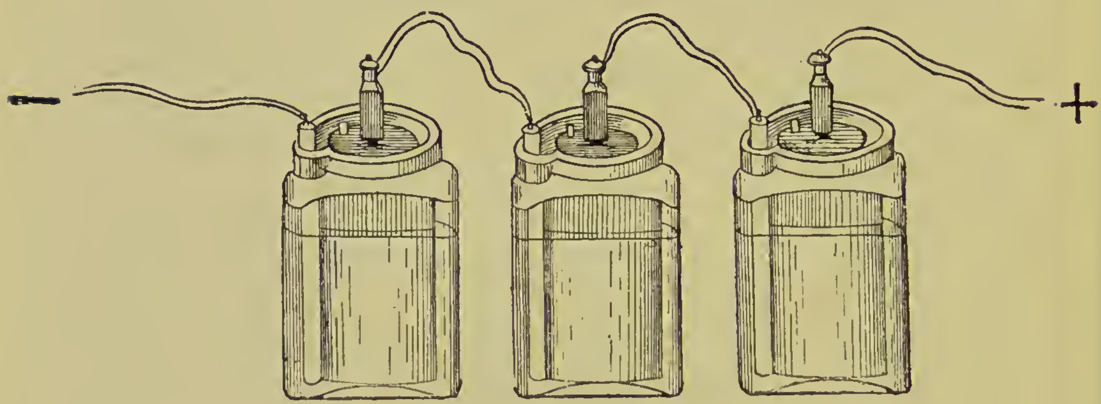


FIG. 10.—CELLS IN SERIES.*

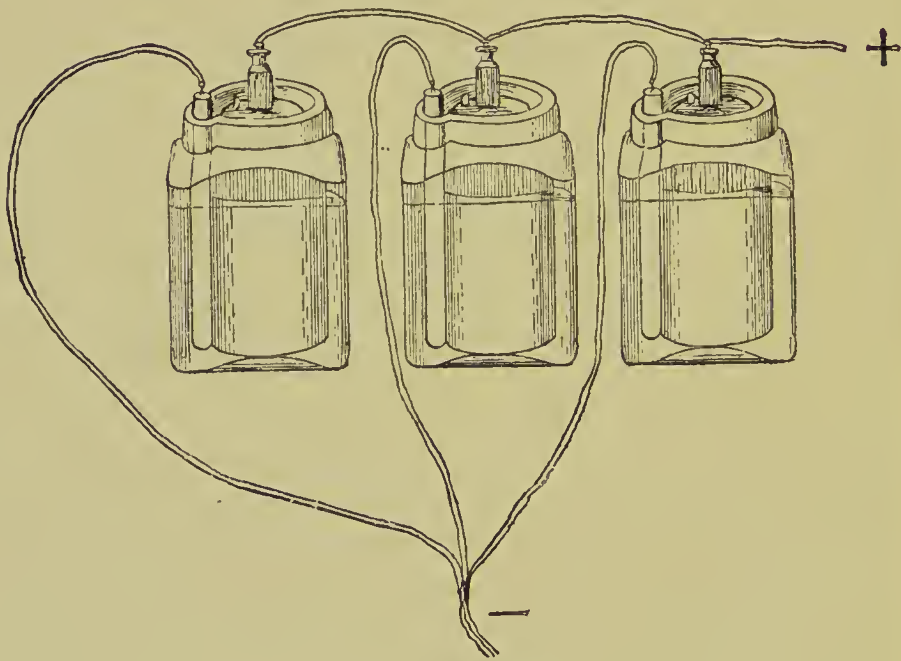


FIG. 11.—CELLS IN PARALLEL.*

pose, for example, there are twelve cells, each giving a current of ten ampères at two volts' pressure. They can be coupled up in the following ways:

* These and several of the foregoing figures are from Dawson Turner's 'Manual of Electricity.' (Baillière and Cox.)

	Series.	*Parallel.*	*Current.*
(*a*)	In twos	In sixes	60 ampères at 4 volts.
(*b*)	In threes	In fours	40 ,, ,, 6 volts.
(*c*)	In fours	In threes	30 ,, ,, 8 volts.
(*d*)	In sixes	In twos	20 ,, ,, 12 volts.

This arrangement is called *multiple series.* The current may also be indicated in watts. A watt equals a flow of one ampère at a pressure of one volt. In the arrangement just described, each gives a working current of 240 watts.

II. THE INDUCTION COIL.

The Ruhmkorf coil is an instrument for transforming an electrical current of low voltage (or pressure) to one of high tension. Its action depends upon the fact discovered by Faraday that an electrified body is capable of inducing a similar condition in an unelectrified body lying within the field of its influence, but not in actual contact. It consists of a core of soft iron surrounded by a helix of thick insulated copper wire, known as the 'primary,' the ends of which are connected to two binding screws on a board that forms a base for the instrument. The thick wire is surrounded with many turns of a much finer insulated wire called the 'secondary,' varying in length from a few hundred yards to several miles. Many methods are adopted for securing good and lasting insulation in the secondary. Of these none is more successful than that of Mr. Apps, the maker of some of our largest and best induction coils, although, of course, other good machines are upon the market. Some of the cheaper forms give a good spark for a time, but the insulation is apt to break down, so that the working part of the secondary wire is shortened, and the length of the resulting spark decreases in like proportion. The ends of the secondary wire are fastened to two discharging rods fixed on the base. If a current of low voltage be now sent into the primary wire, a current of extremely high voltage is induced in the secondary. A sudden break in the current from the primary induces another current in the secondary in the opposite direction. To accomplish this break mechanically, many methods have been devised; the simplest is that of the so-called vibrating hammer. A thin piece of steel armed at one end with a heavy piece of iron is fixed on the base, so that the head of the hammer is exactly

opposite the centre of one end of the soft iron core, at a distance of about $\frac{1}{8}$ inch. Fixed in the centre of the hammer, on the face away from the core, is a piece of thick platinum wire, and opposite this, on a stout piece of brass fastened to the base, is a screw carrying in its point another piece of platinum. Connections are made underneath the base-board, so that the current must pass through the two pieces of platinum when touching each other, into the primary wire. The current immediately changes the soft

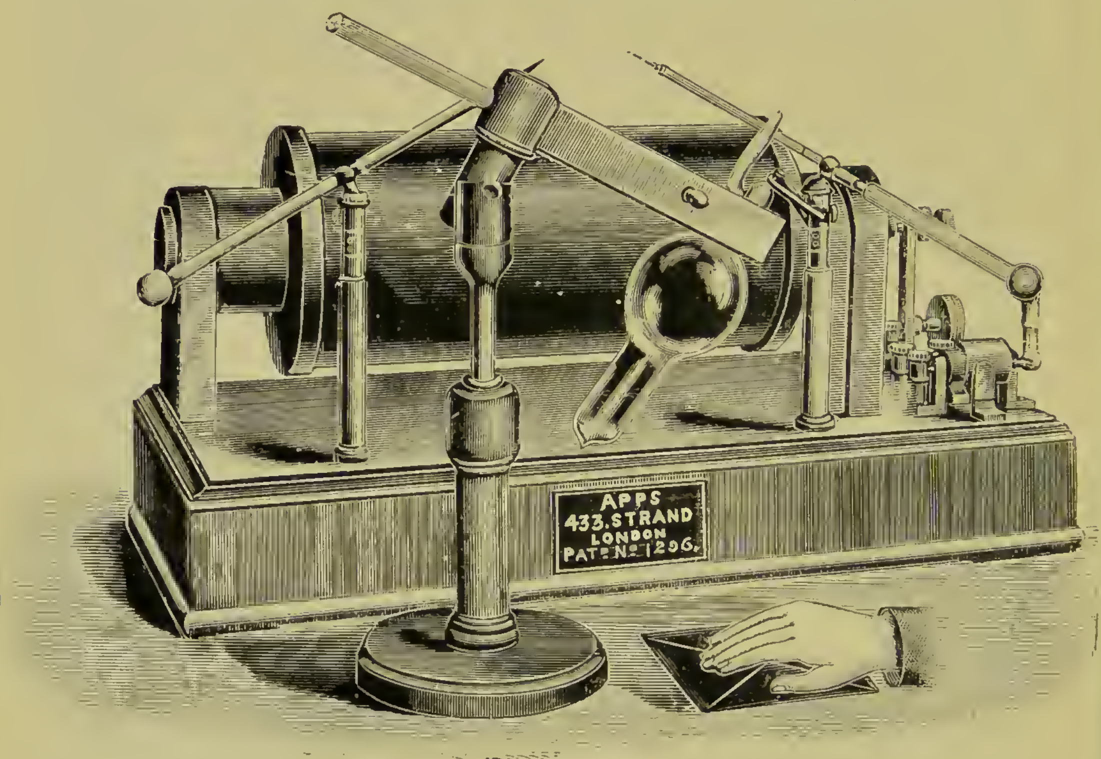


FIG. 12.—APPS INDUCTION COIL, FOCUS TUBE, AND HAND IN POSITION OVER PHOTOGRAPHIC PLATE.*

iron core into a magnet which attracts the iron hammer on the vibrating steel, and the two platinum points are separated. The current ceasing to flow, the core is demagnetized, and no longer attracts the hammer, which falls back to its original position, when the current flows again into the primary and the process is repeated. There must be an arrangement for adjusting the distance of the hammer from the iron core, and of bringing the two pieces of platinum firmly together. This is provided for by Mr. Apps with

* The dark envelope under hand should have *address* side uppermost.

a simple but efficient contrivance. In a box below the base, and forming part of it, is placed the condenser. This consists of a number of sheets of tinfoil insulated from each other by sheets of paraffined paper. The alternate sheets are connected, the even numbers on one side to one of the two supports armed with the platinum points, and the odd numbers on the other side to the second support. The object of the condenser is to demagnetize as quickly as possible the soft iron core, as the length of the spark depends upon the suddenness with which this is accomplished. On breaking contact a current is induced in the primary wire in the same direction as the primary current, which would tend to prolong the magnetization of the iron core if it were not directed into the condenser. The condenser immediately discharges, and produces a reverse current in the primary wire, resulting in the instant demagnetization of the core.

There are many forms of contact breaks of both low and high speed; of the latter Gordon's is a good example, and of the former Foucault's mercury break. In practice it is desirable to keep a spare break at hand, as the platinum points are soon worn away by the action of the current, and the coil cannot be worked again until they are renewed.

Before using the coil these points should always be examined, and if found uneven a fine file should be passed over them until the surfaces are rendered perfectly plane.

Beside the contact break is usually found a commutator or key for making contact or for changing the direction of the current. It will be found desirable to alter the direction of the current at times, or one platinum point will wear out much faster than the other.

III. THE TUBE.

Soon after the invention of the induction coil, it was found that a spark which passed with difficulty in air did so readily in a partial vacuum. A glass tube having a piece of platinum wire sealed into it at each end, and the air exhausted to one-half, was found to glow and give the spectroscopic lines of the residual gases, namely, nitrogen and oxygen, when a current of electricity was passed through it. This apparatus was named the Geissler tube. The phenomena of the striæ, or brush-like sparks, and the sensitive condition of higher exhausts, were carefully investigated

by De la Rue and Spottiswoode. The exhaust was carried still higher by Crookes, who observed a new set of phenomena, and suggested a fourth form of matter, to which he gave the name of 'radiant matter.' It is necessary to carry the exhaust to about one-millionth of an atmosphere to produce his results, which seem to be caused by the action of the negative pole (kathode), and not, as in the Geissler, by that of the positive (anode). The study of the kathodic rays was pursued still further by Lenard and Röntgen, who showed that they could be reflected, refracted, polarized, and deflected by a magnet, just as ordinary light. It was while investigating these that Röntgen made the discovery that there were other rays, to which he gave the name of x-rays. These appear not to conform to any of the laws of light, but they have the special property of penetrating substances opaque to ordinary light and to radiant heat. On this property depends their interest and great utility. The x-rays, or, as they are now more generally named, the Röntgen rays, like the actinic rays, produce fluorescence and photographic action, but do not possess the properties of refraction, reflection, and polarization.

By carrying the exhaust of the Crookes' tubes still further, Röntgen rays of great penetrating power are produced in abundance. The tubes themselves are made in endless variety, the differences being chiefly in the shape and position of the anode and kathode. They may be divided into two groups: one in which the kathodic rays are projected on the inner surface of the glass tube exactly opposite the kathode, and another in which the kathodic rays are first focused on to a piece of platinum attached to the anode. This second form is superior to the first, both in the production of the x-rays and in the sharp definition found in the resulting photographs. Mr. Jackson's improvement of Crookes' tube consists of inclining the piece of platinum at an angle of 45° towards the kathode. The great body of the Röntgen rays is thus directed to one side of the tube, and hence may be readily thrown upon the object to be investigated, whether by the phosphorescent screen or by means of a sensitized photographic surface. Jackson's tube, known as the focus tube, consists of a hollow sphere of glass from 2 to 4 inches in diameter. In one part of its circumference is fused a small straight tube, with a platinum wire terminal for the current carrying at its free end an aluminium disc, which projects into the

globe. The diameter of the disc varies from $\frac{1}{4}$ inch to 1 inch, but the smaller is found to produce equally penetrative rays. At the opposite side of the globe is another small straight tube, in which is sealed a platinum wire. On the free end of the latter, and

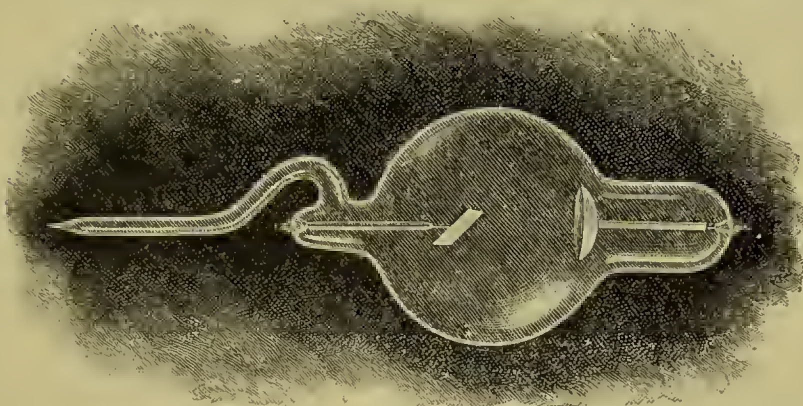


Fig. 13.—Focus Tube for Continuous Current.*

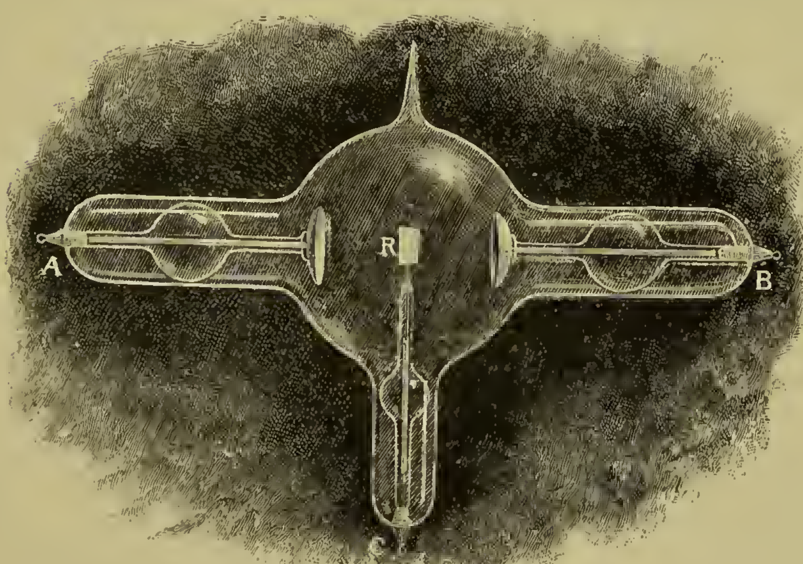


Fig. 14.—Focus Tube for Alternating Current.*

projecting into the globe, is a square piece of platinum foil, fixed at an angle of 45°. A branch from this tube serves as a holder, and is left open for the purpose of exhaust. The aluminium disc is the negative (–), or kathode; the platinum is the positive

* Both these drawings are from 'The Induction Coil in Practical Work,' by Lewis Wright. Macmillan and Co., 1897.

(+), or anode. Sometimes the piece of platinum is not used as the anode. It is then known as the anti-kathode.

For exhaustion the tube is attached to a pump, and the air withdrawn to something less than the millionth of an atmosphere. With a good pump and with an operator who understands high exhausts, a moderate-sized tube may be prepared in half an hour. A special tube is required for use with an alternating current; it has two kathodes (A and B, Fig. 14), and the anode or anti-kathode (C) is placed midway between the two.

IV. THE EXHAUST PUMP.

The form of pump varies almost as much as that of the battery. The mechanical pump, capable of giving a high exhaust, demands special knowledge and aptitude on the part of the operator to be successful. The various kinds of mercurial pump, although fragile, are much easier to work. They are devised upon two methods: the Sprengel, by which the rapidly-interrupted fall of a stream of mercury carries the air out of the pump; and the Toepler, in which by the lifting of the mercury air is forced out of the apparatus (Fig. 15).

If the former be selected, it should have at least six fall-tubes, otherwise it will be found exceedingly slow. From 10 to 20 lbs. of mercury are required to work either form. A drying tube—two if possible—should be attached to each pump, as it rapidly absorbs all moisture, the great enemy of high exhausts. An elementary knowledge of glass-blowing is essential to the use of the apparatus. The Röntgen ray tube should be fused to an outstanding branch of the pump; if attached by any other means, it will be found almost impossible to prevent leakage. There should also be a tube with a tap for connecting a small mechanical pump to the mercurial pump. By means of a few strokes of the former, an exhaust of one-thousandth of an atmosphere is quickly reached, a condition that will readily be recognised by the resistance offered by the piston. If the coil be attached to the tube before starting the exhaust, the spark will pass exactly as in the open air. As the exhaust increases, however, the spark widens out, breaks away from the kathode, and gradually shortens, until a glow surrounds first the anode and then the kathode. Now the mercury pump must be put in operation.

Assuming that the Toepler form has been selected, the vessel containing the mercury is gradually lifted from the floor level, so as to raise the glass valve gently to its position, and to fill the large reservoir by forcing the air out through the barometer tube.

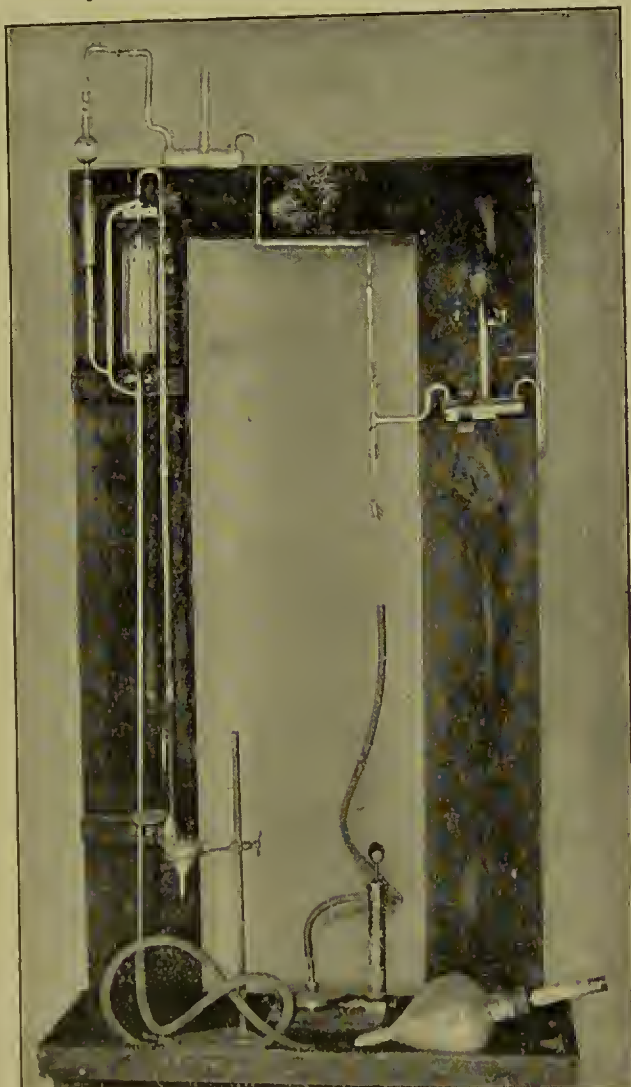


FIG. 15.—TOEPLER MERCURY PUMP.

When no more bubbling of air is to be seen, lower the vessel containing the mercury, taking care to keep it upright, so that no air can enter, and return it to its first position on the ground level. Directly the mercury has flowed back into the vessel, lift the latter and continue the process of lifting and lowering until

the required exhaust is reached. The higher the degree of the exhaust, the more care is required in filling the reservoir, as by any sudden lift the mercury rushes up with force sufficient to break the strongest pump. If while you are exhausting you allow the spark to pass continuously through the tube, you will notice that the glow surrounding the anode gradually disappears, while that of the kathode spreads until it fills the whole tube. A dark space begins to appear round the kathode, and as this increases a green phosphorescence is seen here and there in the tube.

The kathodic glow is focused by the aluminium disc into a distinct stream striking the anode, which it gradually makes red-hot. At this point it is desirable to heat the tube by placing underneath, and almost close to it, a piece of asbestos board, below which is a good Bunsen flame. When the tube is thoroughly heated, another Bunsen flame may be applied directly to the glass ; it must not be allowed to rest on one spot, but passed quickly to and fro above and below, so that the flame may play equally over the whole tube. This second Bunsen should be used occasionally for two or three minutes at a time. Unless these points are carefully attended to, there will be danger of overheating some part of the glass bulb, which will soften and be driven in by the pressure of the outside air, causing the instant collapse of the Crookes' tube. When the dark space reaches as far as the anode, the resistance to the passage of the current increases rapidly, and the whole of the front of the tube is filled with a beautiful golden-green phosphorescence, and if the hand be now placed between the fluorescent screen and the tube, its shadow can be seen on the former. If the tube is to be used with a 6-inch coil, the exhaust should be continued until a 3-inch spark passes with some difficulty ; then the tube should be disconnected by melting in a blowpipe flame, and drawing out the glass tube joining the Crookes' tube to the pump. As the resistance of the tube continues to increase with use, it will gradually exceed the power of the coil. It should then be opened, attached to the pump, and once more exhausted. This resistance may be temporarily reduced by warming the tube for some time before using it, or by running the current for a few minutes in the opposite direction. Various other expedients may be adopted, but it should be clearly under-

stood they restore the activity of the Crookes' tube for a short time only.

V. THE FLUORESCENT SCREEN.

The screen depends upon the property possessed by the Röntgen rays of causing fluorescence in certain bodies, such as platino-cyanide of potassium, platino-cyanide of barium, calcium tungstate, and many other salts. A thin piece of cardboard is covered with three layers of collodion varnish. Before the last coating is dry, either of the above-mentioned salts is sprinkled in a fine powder evenly over its surface. Everything necessary should be at hand, as the varnish dries rapidly. The best sprinkler is a fine wire strainer, held some distance from the cardboard. It is well to practise on a piece of dry cardboard several times, as the operation is by no means as simple as it looks. The efficiency of the screen largely depends upon the evenness with which the cardboard is covered. The following sizes are recommended, 8 inches by 5, 12 by 10, and 18 by 12.

The eye is not readily affected by the phosphorescent light. It is advisable therefore to have the room perfectly dark, to place a cloth over the break of the coil, and to enclose the Röntgen tube in a black paper envelope, so as to exclude all other light. After remaining a few minutes in darkness, the tube may be put into operation, and in dealing with the human body the experimenter will soon learn to distinguish any abnormal conditions of the bones or any foreign opaque substance. The object to be examined should be placed between the tube and the screen, the latter being put upon it with the fluorescing salts outward—that is to say, on the side towards the operator. The screen when not in use should be excluded from light, dust, and moisture.

The cryptoscope does away with the necessity of a darkened room. It consists of a dark chamber, shaped like an ordinary stereoscopic hand-camera. At one end is fixed the fluorescent screen, and at the other are two apertures through which the observer looks.

VI. PHOTOGRAPHY.

A knowledge of photography is essential to the experimenter who wishes to carry out the whole process with his own hands. All the usual dry plates of good makers seem equally sensitive

to the Röntgen rays. Their size will naturally vary according to that of the subject to be taken. They must be transferred from their boxes to the black-paper envelopes in a dark-room. It is better to enclose them in two layers of coloured paper—a first one of orange and a second of black. After exposure, the plate is taken back for development to the dark-room, from which all except ruby light has been rigorously excluded.

Developing solutions may be prepared of pyrogallic acid, hydrokinone, metol, and various other materials. If pyrogallic acid be selected, the following formula will be found to give good results with almost all kinds of dry plates:

STOCK A.

Pyrogallici ac.	1 oz.
Potash metabisulphat.	2 drs. 10 grs.
Ammon. brom.	2 drs. 10 grs.

Water to 10 oz.

B.

Ammonia sol. fort.	5 drs.

Water to 10 oz.

C.

Pyro. sol. (Stock A)	$2\frac{1}{2}$ drs.

Water to 10 oz.

To develop a whole plate, take 2 oz. of C and 1 dr. of B., but do not mix them until you are quite ready to proceed with the development.

Dishes of the various sizes of the plates—the lighter the better* —will be required. Having taken the exposed plate out of the envelopes, place it in the developing-dish, mix the developer, hold the dish slightly inclined from you, and pour the developing solution quickly along the upper edge of the plate, so as to cause it to flow rapidly over the whole surface. Keep the liquid slightly moving, but not so much as to produce bubbles. The picture, if properly exposed, should appear within a minute after pouring on the developing solution. The more gradually it appears the better the picture is likely to be. If after two or three minutes it still lacks contrast, pour off the developer and add to it a little more

* A good form of dish is that made of ebonite or of xylonite.

of solution B, and once more flood the plate. In from five to ten minutes the picture will be fully developed. Practice alone will enable you to decide when this important part of the process has been effected. The plate must now be taken out, well washed, and placed in the fixing solution, which consists of

Hyposulphite of soda	16 oz.
Water	80 oz.

The plate should remain in this until all traces of opalescence have disappeared. It may then be exposed to the ordinary light, and should be washed in running water, if possible, for about an hour, and afterwards placed edgewise and allowed to dry. As soon as it is thoroughly dry, the plate may be placed in the printing-frame, with the film side inward. On this is laid the sensitized paper, which is in turn fastened on with the wooden back. The frame is then exposed to the light (not direct sunlight) until the picture appears in deep tones. This latter fact may be ascertained by raising half of the back and looking at the paper. The print is next placed in running water until all cloudiness of the water disappears. It is then put in a toning solution consisting of

Chloride of gold	20 grs.
Acetate of soda	1 oz.
Water	20 oz.

One ounce of this stock solution should be added to 10 oz. of water for use. Keep the print constantly moving, so that the toning may be evenly effected. When the required tone appears, take the print out and wash it, if possible in running water, for some time. Then place it in the fixing solution, consisting of

Hyposulphite of soda	2 oz.
Water	20 oz.

and let it remain about ten minutes. Once more wash thoroughly and hang up to dry. It is advisable to carry out the washing and toning in subdued light. When dry, the print should be mounted on cardboard. The kind of mount is a matter that will repay attention, as nothing sets off a skiagram more effectively than a good-sized mount with a border of subdued tint and a white centre, either plain or 'sunk.'

The methods of development are legion, but the process above described will be found generally applicable. Most of the

makers of dry plates and of sensitised paper print on the cover of the packets a formula suitable for developing or toning. One drawback to the use of a "pyro." developer is the way in which it stains the hands. To avoid that inconvenience hydrokinone is substituted by many photographers. Indeed, some authorities claim the best Röntgen ray photographic results from slow development with hydrokinone. Metol does not stain the hands, but is apt to cause a troublesome sloughing of skin.

Skiagrams may also be taken direct on sensitised paper. Eastman's x-ray paper, and that of other makers, is used in exactly the same way as the dry plate, but the most rapid paper is not yet equal to the most sensitive plate, and hence longer exposure is required. The advantages of paper are so numerous and so obvious that improvement in the production of it is eagerly awaited by those interested in the art of skiagraphy. In using paper, the operator must take care he presents an absolutely flat surface to the Röntgen rays, otherwise the image may be distorted in a remarkable way, and thus give rise to skiagrams that may entrap the unwary into all kinds of fallacious readings. A good plan is to place the sensitised paper between two sheets of stout paste-board.

VII. STANDS AND OTHER ACCESSORIES.

In addition to the apparatus already described, a stand for holding the focus tube will be required, together with an operating-table, and a small screen mounted so that all ordinary light can be excluded.

Mr. Sydney Rowland has devised a simple and useful stand, by means of which the tube may be fixed in any desired position. His contrivance is specially useful for bedside work.

A simple operating-table can be made of a piece of board 6 feet long, 2 feet broad, and 1 inch thick, mounted on firm supports about 18 inches high. The coil and tube-stand can be placed on the floor, or on a second table close to the patient. By using the small mounted screen occasionally during the process, it will be seen if the tube is emitting rays of good penetrating power. By this simple precaution much subsequent disappointment may at times be prevented. If the skiagraphy can be conducted in a dark room, the ordinary screen will be

available, but if it be in a lighted room it is difficult for the inexperienced eye to determine whether the tube is at its best or not. In the latter case the fluoroscope, which is simply a screen mounted in a stereoscopic camera, will be found of service.

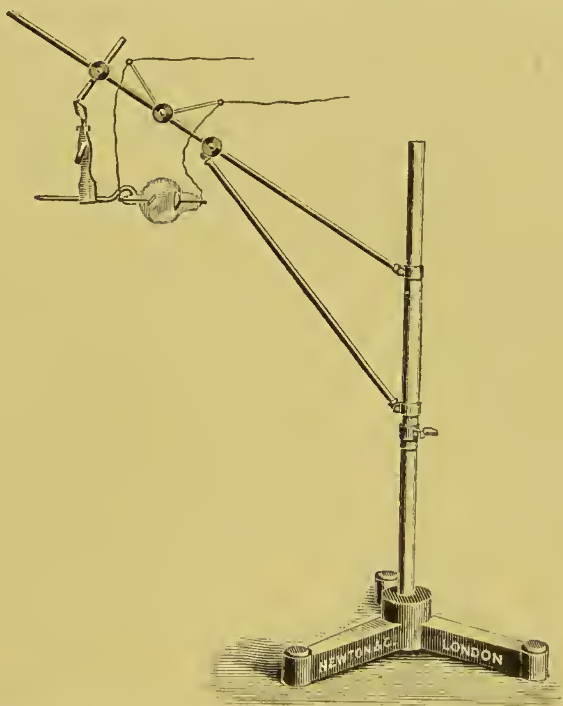


FIG. 16.—ROWLAND'S STAND FOR FOCUS TUBE AND CONDUCTING WIRES. Especially suitable for bedside work.

VIII. PRACTICAL APPLICATION OF THE RAYS.

The proper management of skiagraphy involves attention to a number of details. It can be acquired only by a careful study of the various parts of the essential apparatus, and unless thoroughly mastered, the operator may speedily ruin the best and most expensive coil. In the following description, an attempt has been made to describe the process in a systematic manner, much as it would be carried out in actual practice :

First examine the platinum points of your coil ; see they are not in contact, and are perfectly smooth and even ; also notice that the arm of the switch which passes the current into the 'primary' of the coil points upward. If the condenser be connected to the coil by means of wires fastened to binding screws on the base of

the coil, see that the wires are firmly screwed down. Place the discharging-points opposite each other about ½ inch apart.

The source of supply of the electric current having been tested as already described (p. 19), one end of a piece of thick, well-insulated copper wire, No. 12 B.G., should be firmly fixed in the + terminal of the battery, and the other end securely fastened to the binding-screw on the coil; a second piece of wire should be similarly fixed on the – terminal of the battery and led to the other binding screw on the coil. Examine all the connections of your battery, and see that the wires are clean and firmly screwed down. Every weak or bad connection means leakage of current.

Now turn the handle of your switch to the horizontal position, and bring the platinum points gently together by means of the regulating screw attached to the contact break. A spark will at once commence to pass between the discharging-points; withdraw these until the distance between them is a little more than the spark required to produce the Röntgen rays in the tube. Next increase the pressure of the platinum points by means of the regulating screw until the spark passes once more between the discharging-points. The battery and coil are now in working order and ready for use. Turn off the current by means of the switch. The switch should turn stiffly in its socket, otherwise it is liable to fall and set the coil in operation at a moment when unpleasant, if not serious, results might follow—that is to say, by communicating a shock to the operator or to any other person who might be in contact with some part of the circuit. Two pieces of copper wire well insulated, about No. 24 B.G. should now be fastened, one end of each to the supports carrying the discharging-rods, and the other two ends to the terminals on the focus tube. It is important that the direction of the current between the discharging-points should be known. If when the switch is turned on the space between the aluminium disc (kathode) and the piece of platinum (anode or anti-kathode) is filled with an apple-green light with a dark shadow below the platinum, then the current is in the right direction; but if the green light seems stronger below the platinum and whirls round the inner surface of the tube, the direction is wrong. In the latter case, turn the switch in the opposite direction, and at once the space between the anode and kathode will glow with the characteristic apple-green

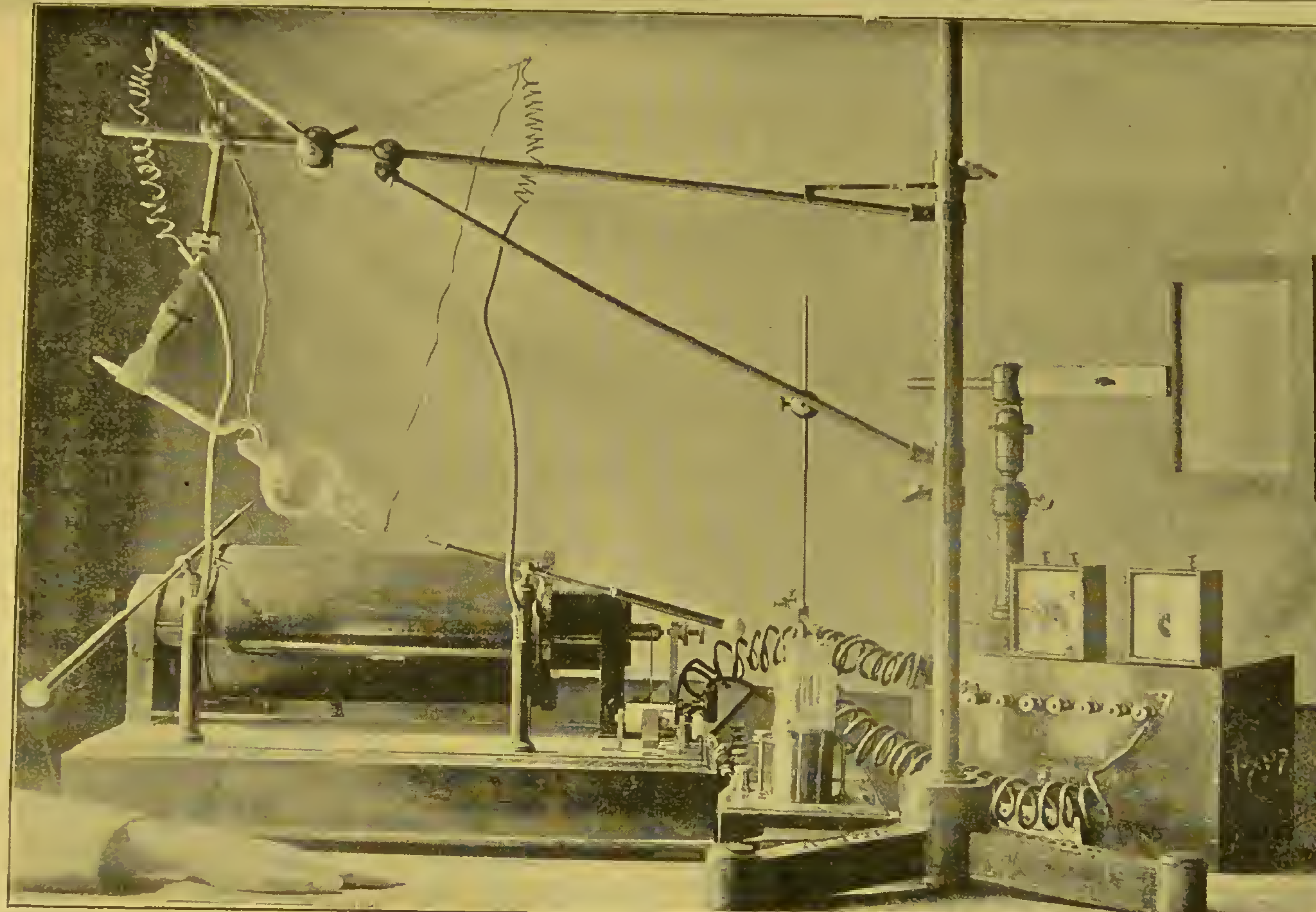


FIG. 17.—COMPLETE APPARATUS FOR RÖNTGEN-RAY WORK, CONSISTING OF SECONDARY BATTERY, VOLTMETER, AMMETER, APPS' INDUCTION COIL WITH ORDINARY AND MERCURIAL BREAK, ROWLAND'S STAND, FOCUS TUBE, FLUORESCENT SCREEN ON STAND, AND HAND IN POSITION UPON PHOTOGRAPHIC PLATE.

colour. By the use of the screen all doubt may be set at rest: with right direction it will fluoresce brightly, and the flesh of the hand placed behind the screen will be easily penetrated, and show the shadow of the bones distinctly; with wrong direction scarcely any Röntgen rays are produced, so that only a feeble fluorescence of the screen can be perceived. Having once found the right direction, make a note of the binding screw of the coil to which the + of the battery is fastened, and also the direction of the handle of the switch. Change the wires of your battery to the opposite binding screws, and you alter the direction of the current; change the direction of the switch handle to the opposite side, and you alter the direction of the current; change both the direction of the wires and the switch handle, and the current flows in the same direction.

Take care that the wires leading from the coil to the focus tube are not near each other, for otherwise the spark will pass between them, instead of through the tube. Much caution is also required to avoid shocks, both from the coil and from the wires leading to the tube. The golden rule for the operator is never to touch any part of the apparatus while the current is 'on.' If any readjustment be required, switch off the current first, and then make the required alteration. The current from a single wire may give a smart shock without causing any serious results, but if the body form a part of the secondary circuit, by contact with both wires at the same time, the consequences might be of an alarming, or even fatal, nature. Too great care, therefore, cannot be taken to prevent the current entering either the body of the operator or that of his patient; the longer the spark used, the greater are the precautions necessary. The focus tube should be fastened firmly in the insulated holder so that the flat terminal of the platinum anode lies parallel to the photographic plate or screen. If the platinum get red-hot, the current used is too powerful, and should be lessened by reducing the pressure between the platinum points by means of the regulating screw. The tube is in the best working condition when the upper surface of the platinum is covered with a green velvety glow, and the under surface shows just a faint redness.

The distance of the tube from the object to be photographed is important. As the Röntgen rays radiate from a point, the near approach of the tube exaggerates the shadow projected upon the

plate. For objects not more than an inch thick, a foot is a good distance, but for the thicker parts of the human body from 20 to 30 inches is desirable. The length of the exposure will vary according to the distance, the penetrating power of the tube, and the thickness and opacity of the object. With a tube exhausted to work with a 4-inch spark and placed 1 foot from the plate, a good photograph of the hand of an adult should be obtained with an exposure of one minute. If the distance be doubled, probably four minutes would be required. It need scarcely be urged upon the beginner that he should become thoroughly acquainted with the apparatus and the methods by which the best results are to be obtained before taking skiagrams of patients. He will find at hand in his own person a fit subject for experiment. When he has succeeded in taking skiagrams of every part of his own body, he will be prepared for the ordinary difficulties of Röntgen-ray photography.

If the plate be not already placed in the protecting envelopes, it will be necessary to go to the dark-room to do so. The film should be placed towards the address side of the envelope. It may be recognised in the dark-room by its dull, non-reflecting surface, whereas the plain-glass side reflects the light distinctly. Do not bring more plates than the one to be used into the operating-room, as they would in all probability be affected by the Röntgen rays, although placed a long way from the tube.

At this point it may be useful to describe the exact methods pursued by the writer, and to cite actual examples. For instance, the case of a fractured forearm, in which both radius and ulna were broken a few inches from the wrist: The limb was placed upon the same table that carried the coil and tube-stand. The patient sat on a chair at a convenient distance, and his splints and bandages were not removed. The sensitive plate, duly wrapped up in black paper, was put on the table with the film side upwards. The arm was next arranged on the plate with the palm downwards and the fractured part as nearly as possible over the centre of the plate. The focus tube was placed 12 inches above the centre of the plate, according to the instructions already given. The switch on the coil was turned in the right direction to produce the rays, and an exposure allowed of five minutes. The tube was examined by means of the cryptoscope, to ascertain if it were

working properly. The plate was afterwards taken to the dark room and developed.

The second case was that of a little boy with supposed double congenital dislocation of the hips. The plate here chosen measured 15 inches by 12, so as to include the whole of the pelvic region and a good part of both femurs. The part to be skiagraphed was relieved of all clothing,* and a warm flannel cloth spread upon the operating-table. The little patient was placed on his back, with a low pillow for the head to rest upon. His legs were placed so as to give the toes a slight outward turn, and care was taken that both were in an exactly similar position. A support was then placed on the outer side of each foot, and a small wedge of cloth between them. An 8-inch spark tube was selected and fixed in the stand at a distance of 24 inches above the plate, and exactly over its centre. An exposure of twenty minutes was then made, and during the whole of that time the tube was working at its best. The plate was then taken to the dark-room and developed. The boy, a bright, intelligent little fellow, was kept interested in the apparatus and various other things. As a rule, children are amused rather than alarmed by the Röntgen-ray process. In this case a perfect skiagram was obtained, but a condition was revealed not coinciding with congenital dislocation.

The third case was that of a man who had been thrown from his horse, and who, amongst other injuries, had fractured the right ramus of the lower jaw. He was placed on the operating-table on his right side, with cushions to support the back. A plate, 15 inches by 12, was placed in the protecting envelopes, the film towards the address side. The injured side of the face was then laid upon the plate, so as to bring the broken bone as near as possible to the sensitive surface. Lastly, the plate was slightly raised, so that the head might be in a comfortable position. A 9-inch spark tube was chosen, as it was necessary to penetrate the left jaw to reach the right. It was placed 24 inches from the plate, exactly over the sigmoid notch of the inferior maxillary bone, during an exposure of twenty minutes. The resulting

* Although the removal of clothing is not absolutely essential, yet it is desirable when taking a skiagram through a thick part of the body, as the pelvis, to remove superfluous clothes, as they offer some resistance to the rays both by their material and also more especially by their dyes.

skiagram showed not only two fractures in the jaw and displacement of teeth, but also injury to the superior maxillary bone.

The fourth case was that of a patient suffering from stone in the bladder. The plate, 15 inches by 12, having been prepared, the clothing was removed, and the patient placed on the table prone on his stomach, with the body inclined slightly to the right side. The tube, worked by a 9-inch spark, was placed 30 inches from the plate over the left side of the sacrum. An exposure of thirty minutes was given. The plate was then developed, and yielded a print that plainly revealed the shadow of the calculus.

In the application of skiagraphy to the teeth, special means must be taken to meet the requirements of the case. As the sensitised surface must be placed in the mouth, glass is almost out of the question. A good celluloid film should be chosen, and cut in pieces about 1 inch by ½ inch. The latter may then be wrapped in black paper, and the whole fastened up securely in thin rubber,* so as to keep out all moisture while in the mouth. The tongue should be pressed firmly against the rubber, in order to keep the plate close to the teeth. The patient should, of course, be placed in a comfortable position, yet so that it is impossible for the head to move during the operation. An exposure of five, or even ten, minutes will be required to get good detail. The tube should be placed not less than 12 inches from the face. For the sake of precaution, the hair can be shielded by means of a thin sheet of lead held in a clamp and placed a few inches from the head. After exposure, the plates are developed in the usual way.

It is obvious that the value of the skiagram can be best appreciated by the skilled anatomist. Yet even to him this new method of investigation presents many difficulties. As a rule, he knows little or nothing of practical photography. Every stage of that process is liable to produce spots and blurs which may mislead the most careful, but which are reduced to a minimum in the hands of a good photographer. Hence it is a distinct advantage, where possible, to leave the development of the exposed plates to such skilled hands. The professional photographer, however, will require some experience in order to obtain the best results, for the development of a portrait or a landscape differs widely from that of a Röntgen-ray negative. Much

* The rubber may be fixed on by a few turns of ordinary sewing cotton.

depends upon knowing what ought to appear upon a plate; that which at first seemed a failure may, if properly handled, prove a great success. Then, of course, it must be borne in mind that the surface of the object or subject close to the plate receives the sharpest definition, and is nearest its natural size, while the farther the parts are from the plate, the more exaggerated and the more indefinite the record that is obtained.

Whatever kind of contact break is used with the coil for the purpose of taking a skiagram, a rapid one is needful for screen-work, otherwise the flickering light produced renders it impossible to obtain any useful or trustworthy information. A highly-exhausted tube should be selected and fastened in the stand, with the platinum anode facing the observer. All light should be excluded from the room, the tube itself covered with black paper, and a dark cloth placed over the contact break. The subject or object to be examined should be placed as near the tube as possible—not more than an inch away from it. As in the skiagram the parts nearest the plate are the most sharply defined, so it is with the screen. If it be necessary to examine the sternum, the tube should be placed at the back, and the screen on the front of the body, with the fluorescing material towards the eye. At first nothing appears distinctly on the screen, but after a time, as the eye grows accustomed to the feeble vibrations caused by the fluorescing material, it also begins to distinguish the strong and sharp shadows of opaque objects nearest the screen. It is practically useless to go direct from strong sunlight to the examination of any fairly thick object like the human body. The eye of the observer, about a foot away from the screen, should take first a general and afterwards a more specific view. Every bone and every articulation should be systematically examined, commencing with the thinner members, such as the hand and arm, the foot and leg. Needles may be fixed in the arm in various directions, both on the side near the screen and on the opposite side, so that an idea may be formed of their relative appearance.

The thorax should next be explored. With the screen on the front of the body, the shadow of the heart is distinctly seen, its pulsations may be counted, and anything abnormal in its position noted. The cavities of the lungs appear bright, and the respira-

tory rise and fall of the diaphragm are conspicuous. The dark shadows cast by the liver and spleen are plainly outlined in the abdomen, but, curiously, the convolutions of the intestines offer a uniform and general resistance to the passage of the Röntgen rays. The pelvic cavity, although more easily examined than the abdominal, presents a still limited field. To examine it, the tube should be placed either between the ilium and the dorsal vertebræ or below the sacrum. As in astronomical photography the sensitized plate reveals thousands of stars invisible through the telescope to the eye, so in skiagraphy the eye fails to perceive on the screen many interesting and important points that are distinctly photographed on the plate. With our present knowledge and apparatus, the screen is useful in the examination of most fractures, both before and after setting, also for detecting and localizing any foreign opaque substance in those parts of the body which the Röntgen rays can readily penetrate. The screen also aids our investigation of the organs contained in the thoracic cavity.

IX. THEORY.

Part I. of this little book is intended to be a brief practical treatise, yet a few words concerning the history and the various theories explanatory of the x-rays may be acceptable to the reader. The interesting phenomena obtained by the discharge of an electric current in a glass tube from which the greater part of the air has been exhausted have been already referred to. They are associated with the names of Geissler and Gassiot. Crookes carried the exhaust much farther, and opened up a new world to scientific explorers. Working in this direction, he produced one of the most wonderful inventions of modern times, the radiometer. But an electric discharge in this higher exhaust revealed fresh phenomena caused by the rays proceeding from the negative or kathode terminal, and hence named kathodic rays. Hertz, Lénard, Röntgen, and others, investigated the special properties of these rays, which, while responding to the tests applied to ether vibrations, were found to possess additional characteristics. It was while studying the latter that Röntgen discovered what he modestly named the x-rays. These new rays, which we prefer to call after the name of their discoverer,

as already stated, do not respond to the tests applied to transverse vibrations of the ether. From the fact that they penetrate material opaque to light rays, and that they affect a photographic plate in the same way as light, Röntgen conceived the idea that the waves might be longitudinal, of very great length, yet of high frequency. This theory has never found much acceptance from leading English physicists.

M. Tesla has suggested that the so-called rays consist of minute particles of matter, but this explanation has gained even fewer adherents than the first. It is now generally believed that Röntgen's rays are transverse ether vibrations of exceedingly short period and wave-length. The proofs of that theory, however, are of a negative character, although recent experiments seem to show slight indications of reflection, refraction, and polarization.

Whatever ultimately may prove to be the true explanation, the discovery of the Röntgen rays has enabled us to take one step higher on the vast ladder of vibrations which Nature has planted between the finite and the infinite.

In concluding Part I. it may be remarked that the somewhat bare outlines of this portion of the work will be to some extent filled in by many practical hints scattered throughout the pages of Part II.

PART II.

MEDICAL AND SURGICAL APPLICATIONS.

By DAVID WALSH, M.D.

It must not be supposed that the advantages to the medical man of Röntgen ray exploration are confined purely to clinical purposes. On the contrary, they are here and there conspicuous in other branches of professional study, such as forensic medicine, anatomy, and physiology. It seems possible, moreover, that they may include a distinct therapeutic value.

In order to deal with the subject systematically, it may be split up into various sections. The following rough classification will be found to cover most of the ground broken by this new instrument of accurate investigation :

A. Surgery.
- I. Foreign Bodies.
- II. Bones, General Remarks.
- III. Fractures and Dislocations.
- IV. Diseases of Bone.
- V. Congenital and other Deformities.
- VI. Mapping of Skin Surfaces.
- VII. Other Surgical Points.

B. Dental Surgery.

C. Medicine.
- VIII. Chest and Abdomen.
- IX. Action on Skin and Internal Organs.
- X. Therapeutics.

D. Obstetrics and Gynæcology.

E. Legal Medicine.

F. Anatomy.

G. Physiology.

H. Veterinary Uses.

A. SURGERY.

When the first Röntgen photographs were published, scientific surgeons all over the world became keenly alive to the possibilities of the situation. So far, they have gained the lion's share of practical help from the new science, but ere long the process will perhaps become of hardly less value to the physician. Among the earlier achievements were the detection of foreign bodies in various parts of the human frame, with many observations, both general and particular, bearing upon fractures, dislocations, and diseases of bones. As methods improve, a greater amount of precise and valuable surgical information will assuredly be derived from the same source. Future success, however, will most likely depend upon the definition not so much of substances that are relatively opaque to the rays, but rather of the more translucent structures, such as soft tumours, gall-stones, abscess cavities, and so on. So long ago as February, 1896, Adolph and Leng recorded the fact that they had obtained a Röntgen ray picture of ordinary connective tissue.

I. FOREIGN BODIES.

In no instance has the skiagraph proved of more immediate practical use to the surgeon than in the detection of foreign bodies. The nature of the embedded substance is of importance, for, in order to yield a readable record, the foreign body should offer a resistance to the rays considerably greater than that of the tissues in which it lies. Thus, a bullet buried in translucent muscle would cast a deep and clear-cut shadow on the sensitive plate or screen, whereas it would be obscured if lodged in more opaque structures. Fragments of glass can be readily photographed, because they resist the rays, but such penetrable

materials as leather, clothing, paper wads, and wood cannot, as a rule, be demonstrated by the skiagraph.

All surgeons know that at times it is impossible by any ordinary method to detect the presence of a foreign body in the deeper tissues. A familiar instance of this uncertainty is that of a needle in the palm, where it may elude the vigilance not only of careful and skilful manipulation, but even of an extensive cutting operation. A striking proof of what can be done by the Röntgen rays under such circumstances is afforded by the following cases that have been brought under the writer's notice.

A lady, who some time previously ran a needle into her hand, had her palm explored by a surgeon, with negative results. A little later a skiagram, taken through splint and dressings, revealed a piece of broken needle lying in the first interosseous space, close to the distal end of the thumb metacarpal. From the information thus obtained the foreign body was readily removed by a second operation. In other words, the skiagram furnished the surgeon with a new and powerful weapon of diagnosis, which denoted not only the presence, but also the exact shape, nature, and position of the body to be removed.

In another case a child suffered for several weeks from a swollen foot, for which no cause could be ascertained. A skiagram, however, showed fixed in the astragalus a broken needle, the removal of which was followed by speedy recovery.

These facts suggest a useful application of the Röntgen rays, namely, to locate a broken hypodermic needle lost in the tissues. As everyone knows, such an accident may be caused by an abrupt movement on the part of the patient. Further, the fragment is apt to wander about in a remarkable way, so that few surgeons would feel justified in undertaking a cutting operation, unless the foreign body could be localized by manipulation, or, more recently, by the x-rays. The danger of such wandering objects in the tissues is obvious.

The opacity of glass* to the rays, probably due to the contained lead and other metals, makes it easy to detect fragments buried in the soft tissues. It is, of course, well known that such splinters may remain embedded for many years, often giving no sign of their presence beyond some slight enlargement and pain

* Potash glass is more translucent to the Röntgen rays than lead glass.

or discomfort on deep pressure. By the Röntgen method, however, a piece of glass may be so exactly defined that the surgeon can cut down upon and remove it without a moment's hesitation. After any injury by glass, indeed, it would be well as a routine practice to examine by the rays, in order to ascertain whether any splinters have been left in the wound. In the following case negative evidence was obtained as to the presence of glass, and positive testimony as to joint mischief.

A. B., a milliner, admitted to the Metropolitan Hospital with the following history: Two months previously her little boy, whom she was nursing, by an unexpected kick broke a wine-glass in her hand. The left forefinger was cut, and severe pain followed, reaching up the arm to the shoulder. A piece of glass was supposed to be in the wound, which was explored before the patient came to the hospital. On admission the wound had cicatrized, but the end-joint of the finger was stiff. The accompanying skiagram (Fig. 18), taken by Mr. Greenhill, of Clapton, proved the absence of glass, but disclosed various changes in the joint. Absorption of the distal end of the second phalanx had taken place, and fibrous anchylosis was diagnosed from (*a*) the appearance on the photograph of a faint line between the phalanges, and (*b*) the clinical condition of the joint.

FIG. 18.—FINGER SHOWING ABSORPTION OF BONE AND FIBROUS ANCHYLOSIS.

Exp. 3 m.; spk. 3 in.; dist. 15 in.

Lead is exceedingly opaque to the rays, and hence the new method does yeoman's service in gunshot wounds. The erratic course taken by bullets after entering the body often renders their discovery, under the conditions of ordinary surgery, a matter of impossibility. By means of a skiagraphic examination, however, the surgeon may in many cases acquaint himself as to the exact whereabouts of the missile, and that without undressing the patient and without taking off

splints and dressings. By such a plan the shock entailed by prolonged probing or manipulation will be avoided.

The difficulty of gaining exact evidence as to the presence of a rifle-bullet was well illustrated in the classical case of Garibaldi. Day after day his medical attendants, surgeons of European fame, endeavoured in vain to find out whether a ball was or was not embedded in the ankle of their illustrious patient. At length Nélaton settled the point by means of the ingenious probe that bears his name, an instrument tipped with porcelain, on which the leaden bullet traced an unmistakable billet. Röntgen, however, has far surpassed Nélaton's plan as regards ease, certainty, and simplicity. Had the skiagraph been available in the case of Garibaldi, a few minutes' exposure would have sufficed to clear up the diagnosis. It is interesting to add that in 1896 the presence of a Japanese bullet in the head of the distinguished Chinaman, Li Hung Chang, was demonstrated by the Röntgen rays during his visit to Europe.

In military surgery the Röntgen processes will certainly prove of great value. On a campaign, where baggage is naturally cut down to the last ounce, some little difficulty will be presented by the cumbersome nature of the necessary apparatus. However, the electrical engineers will no doubt be able to meet the wants of the case. As it is, an ordinary field ambulance waggon may be calculated to carry a ton burden with ease, a weight that would accommodate an x-ray installation with dark room and photographic requisites. In the British army the engineers already possess a photographic waggon, which might be adapted to such work. However, the apparatus would probably be located at a base hospital, and not in the front.

The first opportunity of the trial of the new discovery in actual warfare has been afforded by the Græco-Turkish war. The *Daily Chronicle* proved equal to the demand, and sent off a complete outfit to the seat of the war in connection with its national fund for the wounded. The selection and testing of the various requisites was made by Dr. Barry Blacker, of St. Thomas's Hospital. The following account appeared in the newspaper mentioned on May 4, 1897:

'The apparatus forwarded will consist of an absolutely complete outfit in itself, similar in every detail to the apparatus in daily use at St. Thomas's Hospital, and it will be an excellent

opportunity for testing its utility in military surgery at the seat of war. The x-ray apparatus consists of:

'1. A large induction coil for obtaining the high - tension currents for generating the rays in the vacuum tubes.

'2. A double set of accumulators for supplying the current to magnetize the iron core of the coil, thus rendering the working of the rays possible for very many hours in succession.

'3. A sufficient number of the most efficient type of x-ray focus tubes.

'4. A fluorescent screen, capable of showing every joint and bone in the body, coated with a double layer of platino-cyanide of barium, on which the shadows of the bones and bullets will be cast.

'5. A quantity of Eastman's x-ray paper, with developing solution capable of taking 500 skiagrams, should the operator not have the time at his command personally to see the shadows on the fluorescent screen.

'The secondary winding of the coil is over thirteen miles in length, and will give a heavy discharge over 10 inches of air. Strange to say, the same coils are used in another of the very latest developments of applied electricity — viz., telegraphing without wires by means of invisible rays of a much slower rate of vibration than x-rays are supposed to have.

'It is hoped that it will be possible to use the fluorescent screen to the exclusion of the photographic method, as the position of the bullet or the seat of the injury may be viewed in many positions rapidly, and the time required to develop a dry plate (although much shortened by the use of Eastman's new x-ray paper) constitutes a serious delay to a busy surgeon.'

Apart from military surgery, however, there are numerous gunshot wounds to be met with in civil practice. It is surprising the number of injuries of this kind, accidental and otherwise, that come under treatment in the course of a single year at one of the great general hospitals of the Metropolis. Many practitioners will readily recall the long and fruitless search for the missile that usually took place in their student days. Now all that is changed, and if a bullet be present, it may as a rule be located in a few minutes by the Röntgen ray apparatus, which is now attached to every well-appointed hospital.

One great advantage of the new method is the avoidance of

the risk of introducing harmful micro-organisms into the wound by means of the probe. A further gain is that, with a knowledge of exact location, the surgeon can minimize the extent of his operative measures. The latter point is well illustrated in the following case, reported by Dr. E. H. Lee to the Chicago Academy of Medicine:

'The removal of foreign bodies by means of skiagraphs,' he remarked, 'has opened up a great field of observation in that line. I have in this connection an interesting case, which was that of a policeman who, in pursuing a burglar, shot himself in the heel. The skiagraphs show the bullet embedded in the upper portion of the os calcis. I located the bullet before removing it

Fig. 19.—Shot embedded in Muscular Forearm.
(Taken by Mr. Cox, Parkstone.) Spk. 11 in.

by Girdner's bullet-probe. By the skiagraph it is seen that the bullet is not located in the joint. This is a point which was of the greatest importance, for the joint was not opened during the operation. It was supposed that we could not remove the bullet without opening the joint, and it could hardly have been avoided had we not had such accurate knowledge of the location.'*

It will be seen, therefore, that the skiagraph may furnish, as it were, an absolute chart upon which the surgeon may found, not only his diagnosis and plan of operation, but also the hardly less important point of prognosis.

Fig. 19 gives a good idea of the skiagraphic record obtained

* *The Journal*, Chicago, Jan. 16, 1897, p. 124.

from small shot. It was taken from the arm of a gentleman who had been accidentally shot twelve months previously. Two pellets lie close to the ulna, a small portion of which is portrayed. They caused no trouble, and as the patient was strong and muscular, their presence could hardly have been detected by any means other than the skiagraph. In cases of this kind, where a foreign body has been embedded for a long period of time without giving rise to any inconvenience, it need scarcely be remarked that few surgeons would counsel removal.

The skiagraph of a bullet-wound may help diagnosis in various ways. In the following case, related by Dr. Mandras, it threw light upon an injury of the kind long after its infliction:

'M. B. was struck about fifteen years ago by a bullet from a revolver a little below the distal end of the dorsal surface of the first metacarpal. There was no fracture, but the ball glanced round the bone, and caused an extensive laceration of the tissues at the lower and inner part of the thenar eminence.

'Forty days after the accident the wound was healed, but there was complete loss of power of the thumb. Professor Dubreuil extracted a disc-shaped fragment of a bullet the size of a franc. Soon after a second piece, as large as a lentil, was taken away, followed by a third two and a half months later, but it was a year before the thumb regained its movements.'*

A radiograph of the hand by Messrs. Joubert and Bertin-Sans showed (1) a slight depression upon the metacarpal bone, doubtless due to the destruction of the periosteum by the projectile, and (2) the presence in the ball of the thumb of much metallic débris. By the courtesy of Dr. Mandras, the photograph is reproduced in Fig. 20.

* 'Radiographie en Médicine,' par V. Mandras, M.D., Baillière, Paris, 1896, p. 28.

Localization of Foreign Bodies.

In order to localize the exact position in the tissues of a foreign body, it is often needful to take a second skiagraphic observation at right angles to the first. For instance, let us take Fig. 21, which shows a needle to be imbedded in the finger. With so

Fig. 20.—Thumb showing Absorption of Bone (Distal end of Metacarpal) after Impact of Bullet, and Leaden Débris. (Mandras.)

The above print is from a photographic film and reverses the light and shade of an ordinary negative, just as happens when the skiagram is taken on sensitised paper.

small an object, the surgeon has no clue as to whether it lies back or front of the digit. A cross-skiagram, however, will at once settle the point.

When the fluorescent screen is used, the surgeon might in some cases be able to localize by means of acupuncture needles. Thus, he might take two views at right angles, and in each pass

across the field a needle until it apparently touched the foreign body, or he might first accurately fix the shadow and push an acupuncture needle straight into the tissues in the direction indicated, and then, by a cross-view, ascertain the exact depth to which the needle should be carried. Such a proceeding would obviously be confined in its application to the less vital regions.

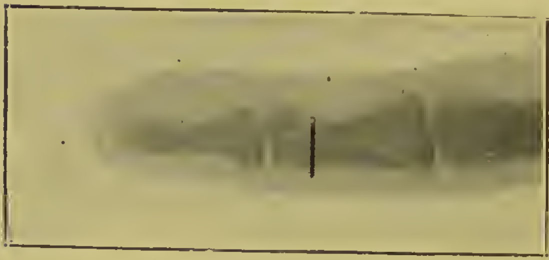


Fig. 21.—Needle in Finger, showing Eye.
Exp. 3 m. ; spk. 2 in. ; dist. 15 in.

Other aids to the correct reading of the skiagram of a foreign body are furnished by (*a*) the sharpness of the shadow outline, and (*b*) its size in relation to the original object. These points are both shown in the following experiment of Mr. Greenhill's. A skiagram was taken of a hand with two sections of bullets exactly corresponding in size, placed, the one on the back of the hand, away from the plate, and the other on the palmar side next to the sensitive surface. The difference in the resulting images was striking. That of the lower one was clear, sharp, and of the same size as the original section ; the other, on the contrary, was darker, larger and more diffuse. This difference in the size of the skiagraphic shadow is explained by the fact that the rays issue from the focus tube in radiating straight lines; the diagram (Fig. 22) will serve to show what is meant. Let F represent a focus tube in action, P the sensitive photographic plate, and A and B two objects of similar shape and size, such as two halfpenny pieces, but A being near the focus tube and B near the plate. It follows, then, as the Röntgen rays radiate in straight lines from F to P, that the shadow *a* will be larger than *b*, inversely to the distance of A and B from the focus tube. In fact, given the distance of tube from plate, and the size of the shadows, the relative position of the intervening objects could be determined by a simple mathematical calculation.

The ring on the same hand showed a bright and a dim outline, corresponding to the near and the far portions in relation to the sensitive plate.

It need hardly be pointed out that the ordinary localizing signs and symptoms, such as pain, tenderness, dyspnœa, and difficulty of breathing or of swallowing, will retain their former value. It should be remembered, however, that such aids to diagnosis are often altogether wanting. In fact, the skiagraph will mean to the philosophical observer an additional instrument for conducting exact investigation into regions hitherto inaccessible either to direct or indirect visual inspection.

In practice, the location of an object buried in deep tissues or in the larger cavities of the body often presents peculiar difficulties. Suppose a bullet to be lodged near the surface of the lung, there would be a better chance of finding its exact position than if it were more deeply embedded. In investigating the brain, the photographic field is obscured by the fact that the rays pass through a large mass of soft material and two surfaces of bone, which under present methods are more or less recorded on the plate.

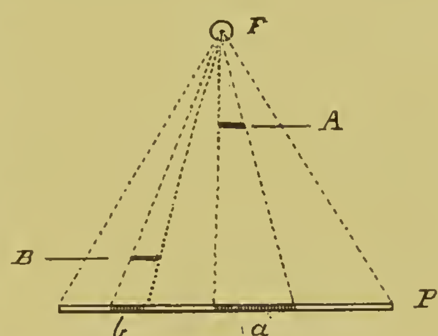


FIG. 22.

In the case of a foreign body in the brain, the action of a cross skiagram may be explained by the following diagram (Fig. 23):

Let *sk.* represent the skull; *f. b.* the foreign body; No. 1 the lamp, and A the sensitive plate used for the first position; No. 2 the lamp, and B the plate for the second position. Then the shadow A1 will fix the plane between No. 1 and A in which *f. b.* lies. The exact point of *f. b.* on that plane is determined by the shadow B2 on the second plate B, which fixes the plane of *f. b.* between No. 2 and B. In other words, the foreign body lies at the point of intersection of the two planes obtained by the two skiagrams taken at right angles the one to the other. In taking the second or cross photograph, the lamp should be placed at exactly the same distance from the plate as in the first exposure. It should also be over an exactly corresponding part of the plate, as, for instance, the centre. In dealing with an oval object like the skull, it will be better to leave the latter in

one position and to move the lamp, placing the plate A on the table, and B at right angles. In practice, however, the results are not so easily obtainable as might be inferred from the foregoing explanation. In the above case, for instance, there would be a good deal of difficulty in penetrating the long axis of the skull, and a somewhat longer exposure would be needed for that position.

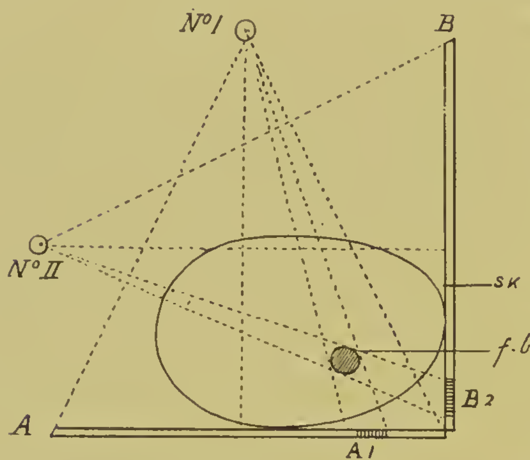


FIG. 23.

Another method, which takes both views in the short axis, is on the principle shown in Fig. 24. Two views are taken by shifting the focus tube, but the body to be penetrated and the sensitive plate remain in exactly the same relative positions. The lamp is put at the same distance from the plate in both views, and also in some known relation to a given point, say the centre or the edge of the plate. By comparing the resulting shadows, a conclusion can be formed as to the intersection of the planes, 1a and 2b. It need hardly be said that two plates must be used, one for each position.

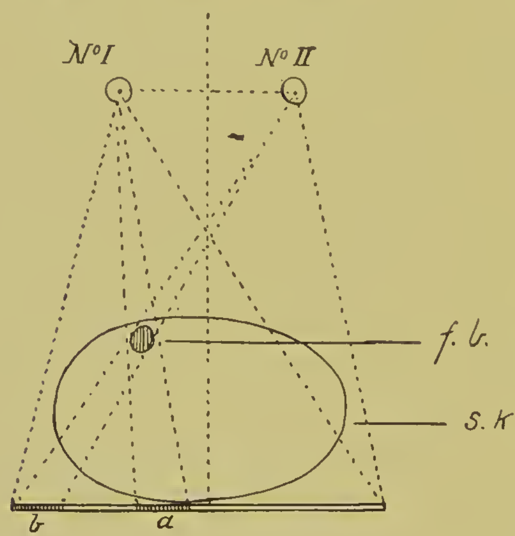


FIG. 24.

The possible alteration of the shape of the bullet should be borne in mind; otherwise, especially if only a single skiagram were obtainable, the observer might be misled by comparing the size of the shadow with the dimensions of the original projectile ascertained from other sources.

Foreign Bodies in Brain.

By the kindness of Mr. Mackenzie Davidson the writer has been enabled to reproduce the accompanying illustration (Fig. 25), showing bullets artificially introduced into the head and neck of a cadaver. Commencing from above downwards, the round ball at the top was placed in the right frontal lobe of the brain, and the conical bullet next to it also inside the brain, close to the right parietal bone. As the right side of the head was placed next the sensitive plate, both these bullets were brought close to the latter, a fact which accounts for their clear definition. For a like reason their shadows in the original photograph correspond nearly in size with those of the foreign bodies. Their sharpness of outline is wanting in the third bullet (from above downwards), which was placed in the centre of the lower portion of the skull cavity, over the basilar process of the sphenoid. The skiagraphic record of the last missile, moreover, would be larger than the original, owing to its comparative distance from the sensitive plate. Much the same may be said of the remaining bullet, which is deeply embedded in the middle line of the muscles of the back of the neck.

Unfortunately, Mr. Davidson has no note of the conditions of exposure. It may be pretty safely assumed, however, that the spark was a powerful one.

It may be also conjectured that the tube was placed close to the skull, and that the exposure was fairly long. Under the conditions mentioned, the side of the skull next the lamp is not reproduced, and a reference to the figure will show that it represents mainly one side of the skull, namely, that next to the plate. Lastly, it will be noticed that the frontal sinus is displayed, that the gums are toothless, and that the tongue is well defined.

The subject of clearness of definition is admirably handled by Mr. Lewis Wright in his work on the 'Induction Coil.' He states that sharpness can be increased in two ways only: (*a*) by increasing the distance of object and plate from the tube, which, of course, lessens photographic power, but is useful in some cases; and (*b*) by reducing the radiant* almost to a point. The following passage is so clear and practical that the intending operator will do well to study it carefully. 'As Dr. Macintyre has pointed out,

* 'The Induction Coil.' Lewis Wright, p. 150. Macmillan and Co., 1897.

the problem confronts us, when we deal with subjects of great depth, in a more complicated way. Suppose we want a radiograph through the entire human body, or through the entire cranium. We have now to consider *what* we want. If we remove the focus tube to a distance proportionate for the much greater thickness, to 9 or 10 inches for the thickness of the hand, our shadow of all the structures would be of approximately equal sharpness. But in the first place, such a distance will afford far too feeble radiation; and in the second place, even supposing that we could thus get shadows of all the structures superimposed, these would only confuse each other. What we want is some definite portion, the less confused by images of the rest the better. These objects are best attained by placing the focus tube as close as possible to the structures we do not want. If we seek for a suspected injury or disease of the bone on one side of the cranium, therefore, we bring the tube close to the other side, and the photographic plate close to the side we wish to photograph. Then the shadows of the side next the tube are so diffused and dispersed and enlarged that they practically disappear; while the details are sharp of the side in contact with the plate.'

An admirable instance of ingenious intracranial localization has been kindly furnished to the present writer by Professor Waymouth Reid, of Dundee. In this instance, owing to the shedding of hair that followed the first exposure to the Röntgen rays it was impossible to procure a cross-photograph.

The patient, a young gentleman, from whom the skiagram was taken, accidentally shot himself by a bullet from a revolver on May 21, 1891. He came under the care of Dr. Blaikie Smith, of Aberdeen, who published an interesting account of his case.* When found after the accident blood and brain matter were oozing from a wound in his forehead, a little above and to the outer side of the right supra-orbital foramen. A director passed into the aperture of the frontal bone, and through the substance of the brain, reached somewhere near the upper extremity of the fissure of Rolando. With regard to the track of the bullet, Dr. Blaikie Smith remarked: 'It seems clear, from the position of the opening in the skull, that the missile penetrated the brain about the lower part of the first frontal convolution.

* *British Medical Journal* for September 17, 1892.

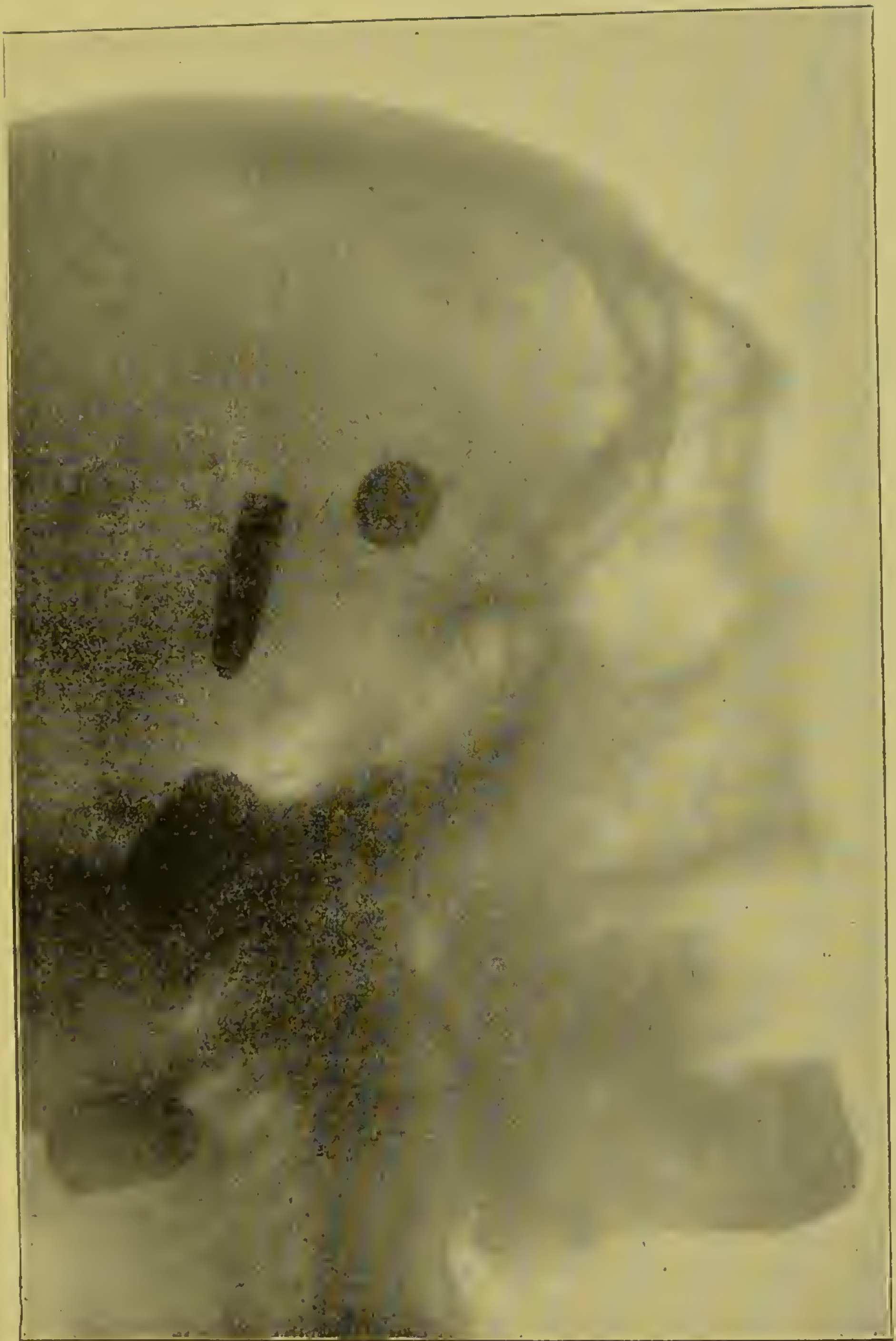


FIG. 25.—THREE BULLETS IN HEAD OF A CADAVER; ONE IN NECK; REDUCED ABOUT ONE-THIRD.

By Mackenzie Davidson, M.B. Ten-inch Apps coil.

BULLET.

+

+

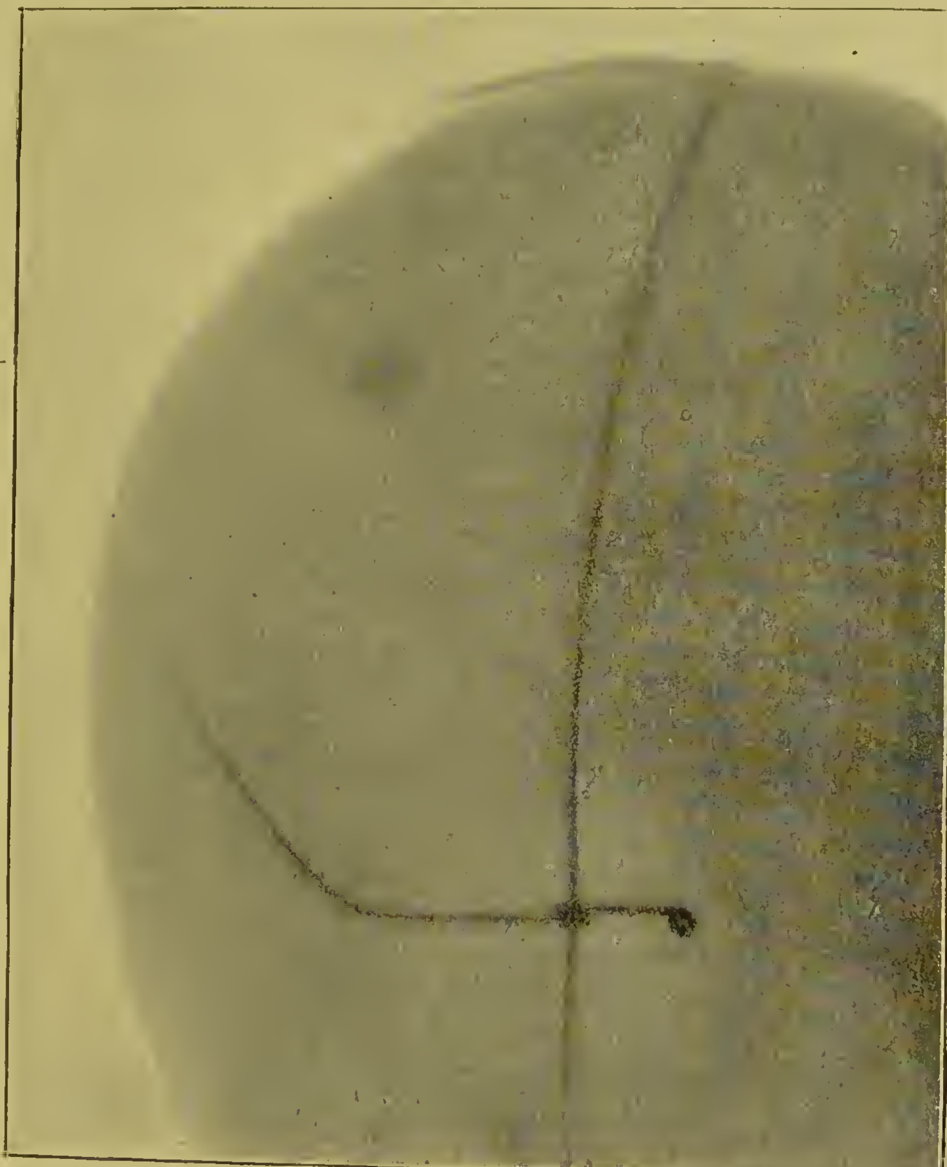


FIG. 26.—BULLET IN BRAIN (OR WITHIN SKULL) OF LIVING SUBJECT. LEAD-WIRE CAGE USED FOR LOCALISING.

(Professor Waymouth Reid's case).

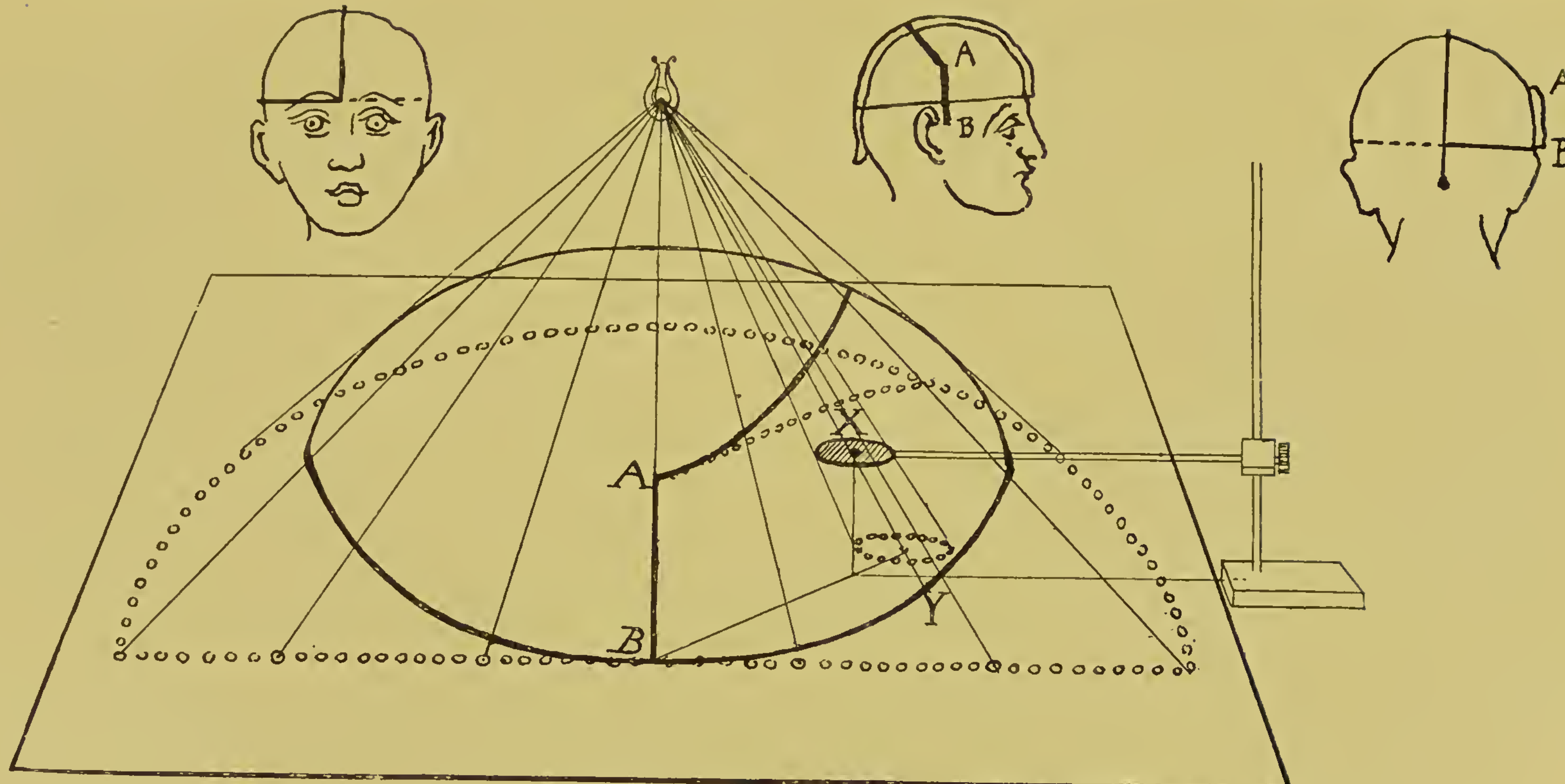


FIG. 27.—Diagrams explaining Dr. Reid's case (see preceding figure).

Continuing its course obliquely upwards through the convolution, it apparently next entered the motor area of the brain, producing, as direct results, paralysis of the arm and leg on the opposite side.'

Strange to say, the patient recovered entirely from this serious wound. Five years after the accident, at his own request, a Röntgen ray photograph, reproduced in Fig. 26, was taken by Dr. Reid, to whom the writer is indebted both for the use of the illustration and for the diagram and notes of his method of localization.

An external landmark was secured by means of a head-cage of leaden wire fitted to the right side of the head, which was placed upon the sensitive plate. The cage was constructed and fitted in accordance with the measurements given by Poirier ('Traité d'Anatomie Humaine,' 1895, t. iii., p. 431).

A tracing of the skiagraphic plate obtained was fixed to a flat surface, and over it was nailed that portion of the wire cage rising vertically from the Sylvian line, so as exactly to cover its own shadow mark (A B in the sketch, Fig. 27). A small surgical incandescent lamp was then suspended at the height of the anode of the focus tube, as measured in the first place when taking the skiagram. The lamp was then moved laterally until the shadows of the cage were cast upon the tracing of the original negative. By that means the incandescent lamp was placed in a position corresponding precisely with that of the anode in the first exposure. Paper discs of varying size were next interposed beneath the rays, X, until their shadows fitted those on the tracing Y. Measurements were then taken upon the curved wires of the lead cage, just as they would be upon a patient's head before operating.

Clearly, the depth of the bullet might be calculated very differently by this method, according to the size of the interposed disc. Accordingly, a bullet of the same size as that with which the patient shot himself was obtained, and three discs were cut—(1) of same diameter, (2) half as large again, (3) double the size.

No. 1 indicated a location on the *left* side of the brain. The shadow on the original skiagram, however, was too sharp for such a position. Moreover, the bullet must necessarily have been more or less flattened by frontal impact. Lastly, the clinical symptoms pointed to a right-sided injury.

No. 2 showed bullet on the right side $1\frac{7}{8}$ inches up from the Sylvian line, $2\frac{3}{4}$ inches back from the vertical rising to Rolandic line (AB), at a depth from surface of 2 inches.

No. 3 fixed the foreign body on the right side close to the surface, $1\frac{1}{2}$ inches above the Sylvian line, and $3\frac{3}{4}$ inches back from the vertical rising to the Rolandic line.

This last inference is probably the correct one. Dr. Reid concludes that the bullet, after it had traversed the brain, came to a dead stop, flattened against the inner surface of the skull.

It is interesting to note that this highly ingenious—indeed, brilliant—skiagraphic diagnosis nearly confirmed that arrived at in the first place by Dr. Blaikie Smith. In his published account of the case, that gentleman wrote : 'In all probability, the bullet has become arrested either in the leg centre or in its immediate vicinity. The exact situation is open to doubt ; *possibly the future may determine its position with greater accuracy than can be done at present.*' In the light of recent events, the remarkable passage printed in italics reads like an inspired prophecy. Dr. Smith, however, has explained to the writer that what he had in mind was the possible future development of localizing signs. He has added that when he last saw the patient the left knee jerk was still exaggerated, and the left hand apt to become cold from slight causes, the latter result being perhaps due to trophic disturbances.

Messrs. Rémy and Contremoulin have devised an ingenious method of localization, which was laid before the Paris Academy of Medicine on March 20, 1897. Having taken two skiagrams by a Crookes' tube in different positions, they were enabled by means of a geometrical figure to determine the exact position of a foreign body. Then, by a special apparatus, somewhat like the compass used by sculptors, they were able to fix with mathematical accuracy the depth of the object from the surface.

An interesting case, recorded by Max Scheir, was that of a man of twenty-seven, who had received a gunshot wound above the right superciliary ridge. From the symptoms it was imagined that the bullet had lodged in the orbit, which was explored, but without success. Five years later the rays revealed a foreign body somewhere near the Gasserian ganglion. A skiagram taken at the time would have prevented the useless exploration of the

orbit. Moreover, had the bullet been removed by operation, the patient might have been spared the ensuing paralyses of the fifth (except its motor branch) and of the olfactory and optic nerves.

Many other bullets have been detected in the brain by the Röntgen rays.* Thus, Eulenburg described two such cases. In the first the foreign body was found in the right middle fossa of the skull, a little to one side of the median line ; in the second it was shown close behind the orbital fissure.

Foreign Body lodged in Spine.

Dr. Phelps, of New York, has reported a case where a revolver bullet struck the thyroid cartilage, and, after passing through the neck, lodged in an unknown part. A skiagram showed a dark spot in the fourth cervical vertebra, and with the knowledge thus gained the surgeon was enabled to operate successfully. The ball had struck the hard lamina of the vertebra and flattened out, after which it had barely penetrated the canal. Recovery was uneventful.

Foreign Bodies in Thorax.

Such objects as coins and buttons have been detected in the larynx by means of the Röntgen rays. Ultimately, no doubt, they will also be discovered more or less certainly when in the bronchi.† In both sites, however, it is likely that the clinical signs and symptoms will afford an equally ready means of diagnosis.

Dr. Walker Downie, of Glasgow, found a pin which had slipped into the larynx from the mouth. The foreign body could not be seen by the laryngoscope, but the patient, a boy, complained of 'a pinching pain at the back of the throat, and some pain in swallowing.' The pin was discovered by the rays, and easily extracted by external operation.‡ Dr. Downie has kindly allowed the accompanying reproduction (Fig. 28) of his original skiagram. It was taken with an exposure of eight minutes to an Apps coil having a 10-inch spark.

* *Deutsch. Med. Wochenschrift*, August 17, 1896.

† Mr. Ballance has recently found a piece of glass in a child's bronchus.

‡ *Edinburgh Medical Journal*, January, 1897.

Fig. 28 shows parts of upper and lower jaws, with some of the molar teeth and their fangs. To the left are several of the cervical vertebræ, and in front, under cover of the lower jaw, is the hyoid bone, below which a light perpendicular band indicates the position of the larynx and trachea, structures which are particularly translucent. Crossing this light area, at the level of the lower border of the body of the fourth vertebra, is the pin with the head anteriorly, corresponding to the outline of the thyroid cartilage, and with its point embedded in the cartilaginous disc between the fourth and fifth cervical vertebræ. The pin appears at least a quarter of an inch longer than the antero-posterior diameter of the larynx, and it is bent near the middle, with the convexity directed upwards.

In an antero-posterior skiagram the pin was localized by means of two pieces of silver wire fastened with sticking-plaster, the one in the middle line, and the other at right angles in a carefully-noted position. In the picture the two wires were shown fixed to the skin, and $\frac{11}{16}$ inch above the horizontal one was the image of the foreshortened pin, with the head close to the middle line, from which point the body of the pin was directed upwards and backwards. It is interesting to note that there was no indication of the vertebræ, through which the rays must have passed to give the image of the pin shown in the photograph.

The principle of localizing by means of wires is capable of extensive application. Soft lead wire is suitable, and may in many cases be twisted round a limb. If fastened on with plaster, it should be remembered that some forms of that material are opaque to the rays, owing to the contained lead.

The beginner will do well to study all the figures attentively. In this way he will train his eye to the recognition of skiagraphic objects, and will also prepare himself for the more difficult task of reading the fluorescent screen. Unfortunately, there is a loss of detail in almost any kind of reproduction for book illustration. This is especially the case when the original skiagram is reduced on the block.

In the œsophagus it is fairly easy to locate false teeth and other objects opaque to the rays. A London medical journal* recently commented on a case where the results of such an attempt, although negative, were nevertheless of an instructive nature.

* *Medical Press and Circular*, January 13, 1897.


PLATE 28.

The facts were briefly as follows: A young lady swallowed by accident a set of false teeth. She called in a medical man, who, failing to remove the impacted plate from the gullet, pushed it, or thought he pushed it, down into the stomach. Some time later she went to a hospital, complaining of pain in the abdomen, and that region was skiagraphed, but without result. Shortly afterwards she brought up a quantity of blood, and was taken to another hospital, where she died while an attempt was being made to skiagraph the abdomen, to which part pain was referred to the last.

Post-mortem it was found that the plate had lodged in the œsophagus below the bifurcation of the trachea, whence it had ulcerated into the aorta. This case suggests the advisability of examining the thorax at once by means of the rays whenever a person has been unfortunate enough to swallow a dental plate.

If a foreign body be found impacted in the upper part of the gullet, the surgeon may decide forthwith to perform an œsophagotomy. Indeed, it is chiefly on account of the difficulty of localizing such objects that this operation has been hitherto of rare occurrence. As in the foregoing instance, where a foreign body is impacted in the gullet, the occurrence of gastric pain is apt to be misleading. Dr. Macintyre has described a case where a boy swallowed a halfpenny some six months previously. The fluorescent screen showed the coin to be lodged opposite the third dorsal vertebra. In that instance the pain was constantly referred to the stomach. Indeed, where pain in that region cannot be explained by some obvious cause, the surgeon will do well to make the skiascopic examination of the chest a routine practice.

An excellent example of a coin impacted in the œsophagus is shown in Fig. 29. The case was brought forward at the Clinical Society of London on June 22, 1897, by Mr. Bowlby. The patient, a boy three and a half years of age, was under the care of Mr. Howard Marsh. He had been under observation for five weeks, during which time he showed no symptoms beyond occasional sickness. A skiagram taken by Messrs. Allen and Hanbury, of Wigmore Street (Fig. 29), at once revealed the presence of the coin, a halfpenny piece, lodged in the gullet at the level of the second dorsal vertebra. Removal was ultimately

effected by means of a catch carried within a gum elastic catheter.

Dr. Mayo, of Rochester, U.S.A.,* has reported a case where an open buckle was shown by the skiagraph to be impacted in the gullet of an infant. The buckle lay behind the upper part of the sternum, with its teeth projecting upwards and to the right. A left œsophagotomy enabled the surgeon to remove the foreign body by means of a bent probe. The chief point of interest here is that the position of the teeth would have effectually prevented the pulling upwards of the buckle. The danger of attempted extraction by curved forceps would obviously have been great.

Professor White, of Pennsylvania, had a child, two years and five months old, brought to him with an obscure history of dysphagia and vomiting. The Röntgen rays showed a cruciform toy known as a 'jackstone' impacted in the œsophagus on a level with the space between the second and third dorsal spines, a little above the bifurcation of the trachea. The object was in the shape of a Maltese cross, with an additional bar at right angles through its centre. As it could not be extracted by the mouth, gastrotomy was performed, and the 'jackstone' drawn down into the stomach and removed.

Among numerous other instances, the following may be selected. Dr. Bliss† found an iron staple an inch long, with two sharp points, so fixed in the gullet that the use of a probang would have still further impacted the foreign body. Removal could not be effected by curved forceps until the exact position of the staple and the direction of its points had been localized by means of the Röntgen rays.

In this class of cases the importance of the Röntgen rays can hardly be over-estimated. As every surgeon knows, the difficulty of locating is often extreme. Undetected foreign bodies in the gullet have been treated for pulmonary phthisis, croup, catarrh, asthma, and so on. Wallace of Edinburgh has recorded a case where a plate bearing six artificial teeth could be located only after repeated negative attempts with the œsophageal olivary bougie and 'coin-catcher.' A low œsophagotomy proved a failure, and gastrotomy was finally required.

* *North-Western Lancet*, March, 1897.
† *Internat. Med. Mag.*, March, 1897.

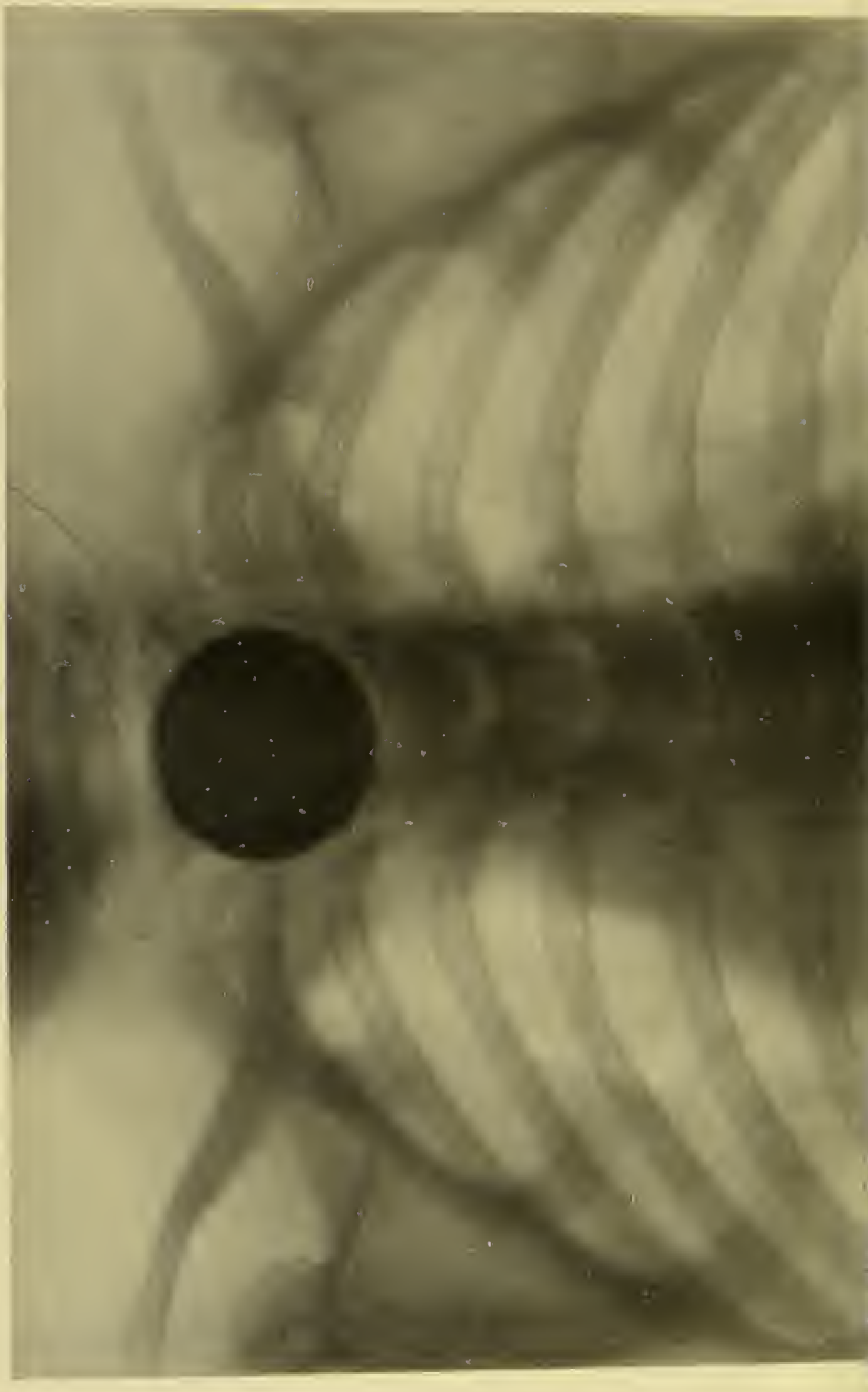



PLATE 29.

Finally, White has suggested the combined use of instruments, as the curved forceps, with the fluorescent screen.

Foreign Bodies in the Abdomen.

So far as the abdomen is concerned, coins and other foreign bodies have been located in the case of children. The importance of exact information of this kind will be at once recognised by those who are familiar with the needs of abdominal surgery. The results of skiagraphy, so far as concerns the abdomen in adults, have been either uncertain or negative. However, a good definition of intestines and other abdominal organs can be procured in the case of small lower animals, and also of children. In the face of such facts, it may be confidently anticipated that before very long it will be possible to obtain satisfactory ray pictures of the abdominal viscera in the adult human subject. From time to time different experimenters have succeeded in obtaining an obscure record of intestines. The present writer has such a result in the shape of a skiagram showing a faint, but discernible, tracing of colon, of loops of small intestine, and of the sigmoid flexure of the rectum. The patient from whom the skiagram was taken had signs of chronic intestinal obstruction. On the chance of localizing the lesion, he was given bismuth in 10-grain doses thrice daily for over a week before the abdomen was skiagraphed.

The advantages of localization of foreign bodies in the intestines of adults need hardly be pointed out. Numerous possibilities will readily occur to the mind of the medical reader, such as the tracing of a Murphy's button during its passage through the bowel.

Foreign Bodies in the Eye.

The Röntgen ray exploration of the eyeball, buried, so to speak, in a dense bony socket, is attended with much difficulty. However, it has been carried out successfully by several observers, and in a certain class of cases appears capable of yielding useful results.

So early in the history of skiagraphy as March, 1896, Professor

Van Duyse communicated some interesting experiments to the Medical Society of Gand. He introduced a shot into the eye of a rabbit, and pushed it up behind the iris towards the centre of the lens. He then, with the aid of a local anæsthetic, produced an exophthalmos, and slipped under the protruding eyeball a small sensitive plate. The result, an extremely sharp shadow, is shown in Fig. 30.

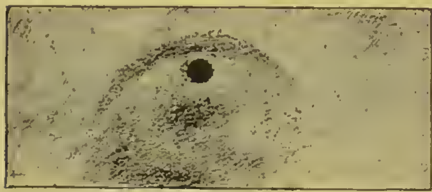


Fig. 30.—Shot in Eyeball of Rabbit.

An important point is that the foreign body could not be detected by the ophthalmoscope.

This second skiagram (Fig. 31) shows a pellet and a fragment of lead introduced into the equator of a human eye after removal from the body. His main conclusion was as follows: 'To obtain a shadow of metallic bodies lying in the anterior chamber, it will suffice to place, in the inner angle of the lids, a small sensitive plate or film of which one of the corners has been rounded, and to turn on the x-rays from the temporal side.'

Fig. 31.—Pellet and Fragment of Lead in Human Eye. (Van Duyse.)

For the blocks of both the above illustrations the writer is indebted to the courtesy of Dr. Van Duyse.

Cases have been reported of the detection by the rays of foreign bodies in the living human eye.

Dr. Leukowitsch* has obtained good results in sheep's eyes with two tubes, but found it better to use one tube and take two views.

For the living human eye he used small semicircular sensitized plates, as that shape allowed the largest possible area to be inserted at the inner angle of the eye opposite the lachrymal bone. By rolling the eye inwards or outwards, a large part of the globe could be brought within range of the rays. Rotation,

* *Lancet*, August 15, 1896.

however, rendered a fixing-point necessary. This he obtained by a glass indicator, bent twice at right angles, with a short straight terminal placed so as to point exactly to the antero-posterior axis of the centre of the cornea. In this way he obtained localizing skiagrams of a foreign body (a sequin) placed on the conjunctiva of his own eyeball.

In February, 1897, two cases of steel fragments in the vitreous humour were brought before the Ophthalmological Section of the College of Physicians, Philadelphia, by Drs. Oram Ring and Hansell. The latter gentleman mentioned another instance communicated to him verbally by Dr. de Schweinitz, who found a foreign body by the rays, and afterwards extracted it by the Hirschberg magnet. Dr. Hansell, in a communication to *The Journal*, Philadelphia, observed: 'Thus it will be seen that the bony walls of the orbit and the coats of the eye are permeable to the rays. By comparison of the shadow of the metal with that of the margin of the malar process of the superior maxillary bone, and the knowledge of the relation of the Crookes' tube to the sensitive plate, the location of the foreign body can be closely estimated.'

So far as we can judge, the field of practical usefulness of the rays to the ophthalmic surgeon is likely to be confined within a narrow limit. Dr. Stern, of the Philadelphia Polyclinic, however, claims by an original method to have succeeded six times in demonstrating in the eye, by both fluoroscope and skiagram, foreign bodies undiscoverable by other means. In each instance he reported subsequent removal by ophthalmologists. Before he detected the fragment in the case of Dr. de Schweinitz's patient, the eye had actually been cut down upon once, and the magnet applied three times with negative results.

In March, 1897, Benedikt* showed a skiagram of a man who had been injured in the right temporal bone several years previously. Since then his vision had gradually declined, together with the occurrence of retinal detachment. The onset of pain led to a skiagraphic exploration, which revealed a sharp body penetrating the orbit from the neighbourhood of the zygoma.

The humours of the eye appear to be somewhat resistant to

* *Medical Press and Circular*, April 7, 1897, p. 359.

the rays, and the crystalline lens markedly so, while the retina is insensitive to their influence.

Calculi in Various Positions.

The detection of stones in internal organs, closely connected with the subject of foreign bodies, is likely to become an important branch of skiagraphy. Under present methods, however, results are uncertain. For all that, calculus has been shown by the skiagram to exist in the gall bladder, in the urinary bladder, and in the kidney of the adult living human subject.

So far as the opacities of the various calculi are concerned, both Neisser and Petersen have demonstrated that while cholesterine concretions are almost transparent, those of phosphates and urates are opaque to the rays. From these premises they concluded that it would be impossible to detect gall-stones by skiagraphy, yet stone in the bladder and the kidney might be thus demonstrated. As already stated, this theoretical conclusion has been more or less upset in practice. Thus, a plate shown to the writer exhibited a faint but unmistakable shadow of a gall-stone. It was taken by Mr. Cox, of Parkstone. The image was too faint to print, but, as often happens with objects translucent to the rays, could be distinctly recognised on the negative. Such evidence, however, is of value, and, so far as one can judge, is all that is likely to be forthcoming for a considerable time in the case of biliary calculus.

Messrs. Laurie and Leon, in a paper in the *Lancet*, January 16, 1897, published results of experiments showing that calculi of oxalate or of phosphate of lime were more opaque than bone, uric acid of almost the same opacity, and gall-stones very slightly more opaque than flesh. They thus substantially confirmed previous results arrived at by Mr. Henry Morris. Experiments upon gall-stones have been reported by Messrs. Neusser, Goodspeed, and Cattell* and many others.

In France, Messrs. Chapuis and Chauvel have specially studied kidney calculus in relation to the rays. They conclude that stones composed of uric acid, urates, and phosphates, are little less opaque than bone. Those composed of many layers and

* *Medical News*, February 15, 1896.

of unequal opacity proved by analysis to consist of uric acid nuclei covered with layers containing phosphates. They found the kidney substance less penetrable than muscular tissue, so that the kidney appeared as a light patch on the negative (dark in the print).

In a skiagram of a removed kidney a stone shows as a dark body. Many excellent examples of this sort have been published from time to time.*

To Dr. Macintyre, of Glasgow, belongs the distinction of having obtained the first skiagram of a renal calculus *in situ*.† It appears that he had failed to demonstrate any concretion in half a dozen cases where stone in the kidney was suspected. Undeterred by these negative results, however, he tried the Röntgen rays upon another patient who had been previously operated upon for the malady in question. Thereupon, with a 6-inch spark and twelve minutes' exposure, he was rewarded by a clear record on a Paget XXXXX sensitive plate. 'In this instance,' to use his own words, 'at the correct situation, a picture of an obliquely-placed elongated deposit was obtained.' From his reading of the skiagram, Dr. Macintyre inferred the presence in the kidney of a stone, but not a well-formed one. The correctness of his inference was subsequently proved by Mr. Adams, of Glasgow, who, on operating, found at the bottom of an old cicatrix an ill-defined mass, which he removed with a spoon.

Messrs. Leon and Laurie, in the paper above referred to, obtained a 'faint but distinct image' of a stone introduced into the urinary bladder of a cadaver. They made an exposure of thirteen minutes with a 6-inch spark, the body lying on its back It is noteworthy that in their experiment the spine itself was very faintly indicated.

The same experimenters obtained a skiagram of a stone in the living subject, a boy eight years of age, after an exposure with a 6-inch spark of seven minutes to a XXXXX Paget plate. The stone was removed a few days later with a lithotrite by Mr. Silcock. A collotype of this calculus, which appeared to be a little over an inch in diameter, was published in the *Lancet*. Subsequently another stone was demonstrated in the bladder of a boy of fifteen.

* See plate in Morton's '*X*-Ray,' New York, 1896.

† *Lancet* for July 11, 1896.

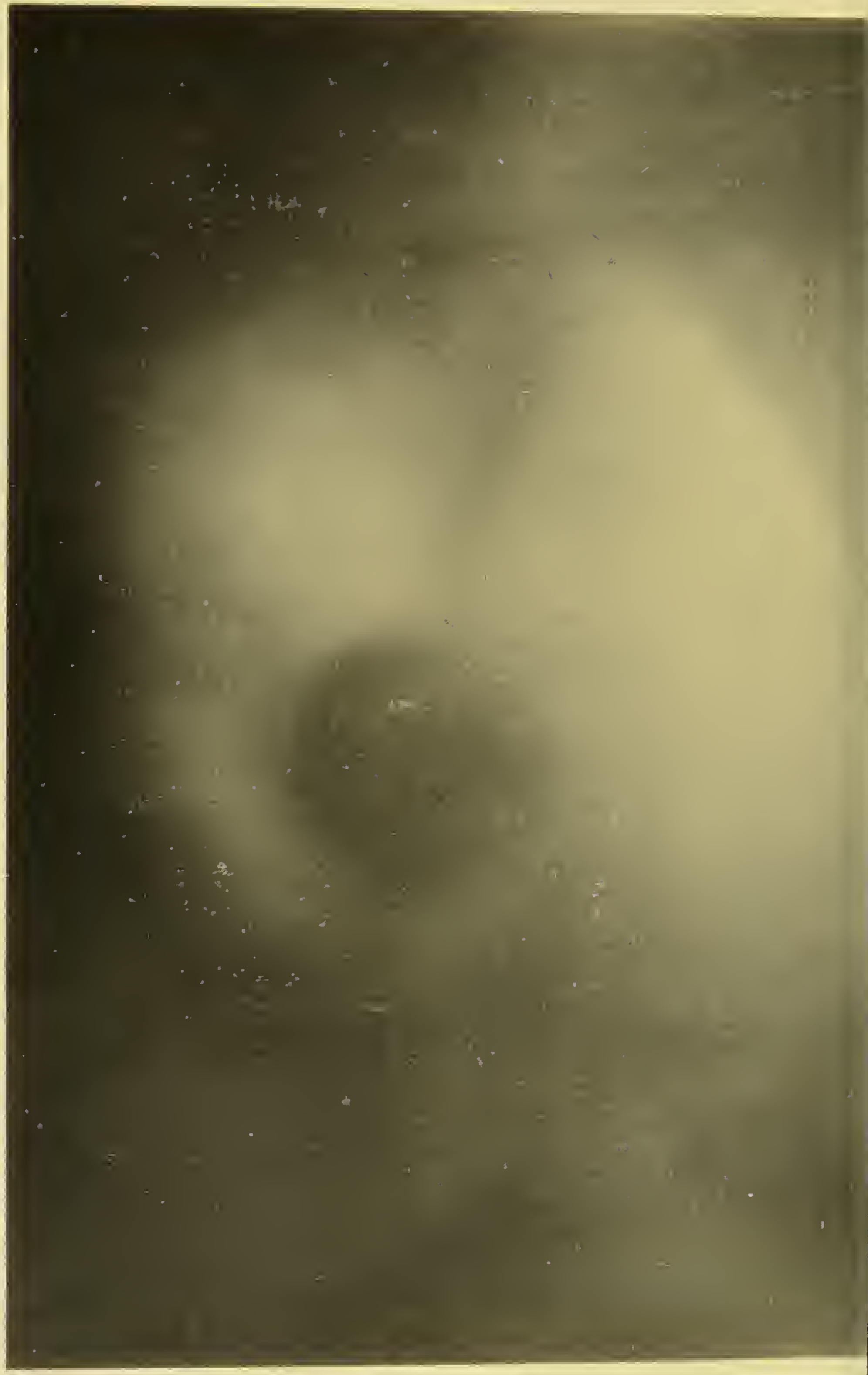
Dr. James Swain, of Bristol, has made some important observations on the subject. He exposed on a single plate various kinds of calculi of nearly uniform thickness to the rays for periods of one, two, four, eight, and sixteen minutes. He found the general law laid down by Röntgen, namely, that the denser the object the deeper the shadow, did not apply exactly to these experiments. Arranged in the order of the highest specific gravity, the greatest permeability to the rays, and the greatest density of the shadow, the results are :

Specific gravity.	*Permeability.*	*Density of shadow.*
1. Oxalate of lime.	Biliary.	Oxalate of lime.
2. Uric acid.	Uric acid.	Phosphatic.
3. Phosphatic.	Phosphatic.	Uric acid.
4. Biliary.	Oxalate of lime.	Biliary.

Dr. Swain exposed each of the above kinds of calculi, together with a piece of human rib and a portion of kidney. With each increase of exposure the shadows became fainter, until at length, after an exposure of sixteen minutes, only the oxalic acid and phosphatic calculi, with the merest trace of rib, were to be seen. The important deduction is that a short exposure may give a better result than a long one. If the exposure be too long, some calculi will disappear altogether.

The uric acid calculus in an eight minutes' exposure gave a less dense shadow than that of rib, and much less, again, than that of a piece of rib covered with kidney. The difficulty of diagnosing uric acid calculi is therefore obvious.

Prolonged exposure caused a 'denser' negative. Objects that could not be printed were still visible to the eye. Hence it is always desirable to study the negative to avoid missing shadows not evident in the print. This observation was applied by Dr. Swain to a case where a patient was suspected to have a stone in the kidney. The skiagraphic negative showed a distinct shadow in the region of the left kidney, but no satisfactory print was obtainable. This result was taken as confirmatory, and a subsequent successful operation removed a stone half as large as a walnut. In this case it is important to note that the shadow given after an exposure of thirty-five minutes was not very deep, but with an exposure of twenty minutes the presence of the



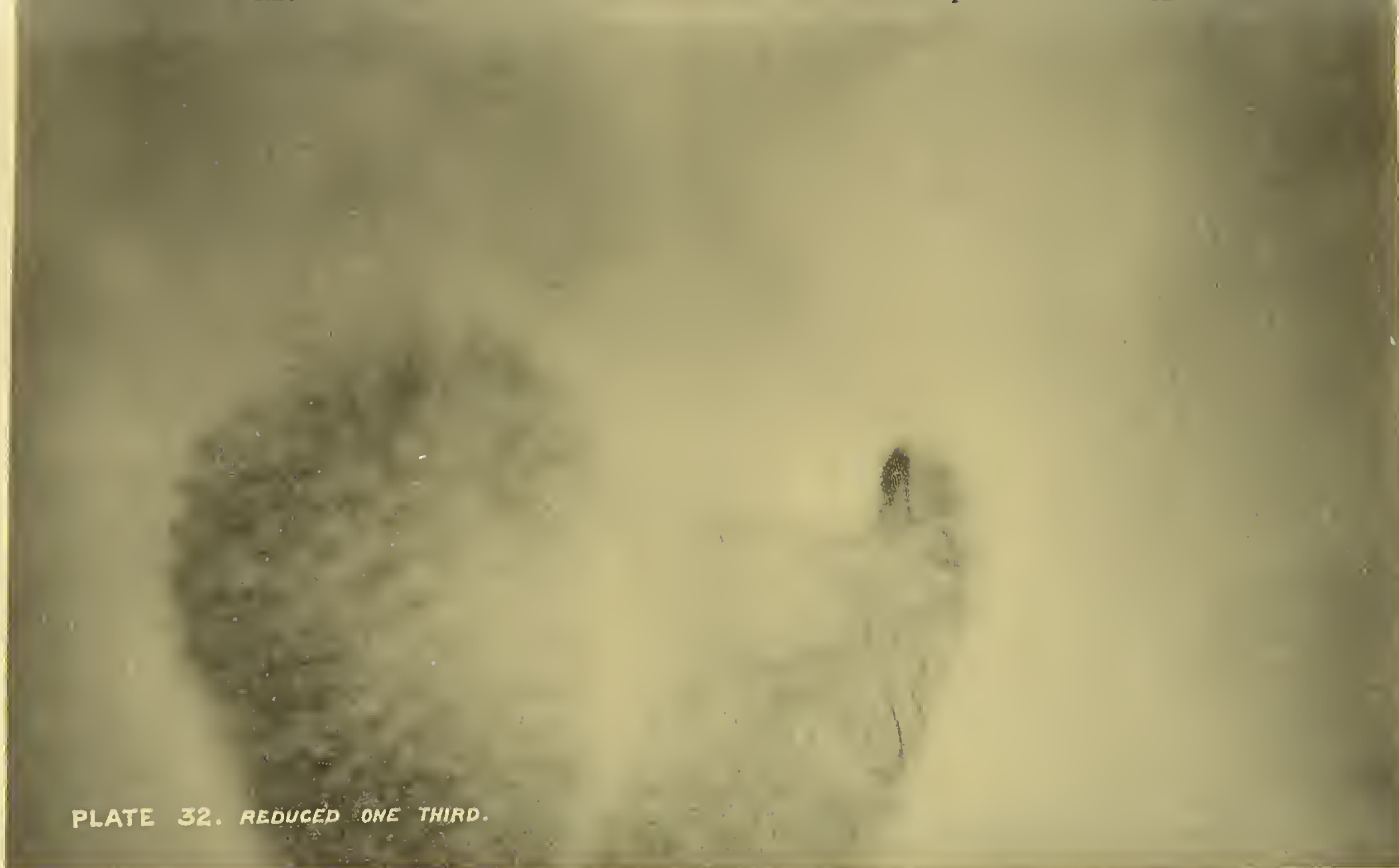


PLATE 32. REDUCED ONE THIRD.

calculus was made abundantly clear. In this case the skiagrams were taken with a coil capable of giving a spark of 19½ inches, worked at about half its full strength. The focus tube was placed about 12 inches from the body.*

It seems tolerably certain, then, in the light of what has been already done in this important branch of surgery, that the demonstration of all internal calculi of any size in the adult will sooner or later be within the power of the Röntgen ray operator.

The accompanying excellent skiagram (Fig. 32) was kindly furnished the writer by Mr. Mackenzie Davidson, M.B. It shows very clearly a uric acid calculus in the urinary bladder of a living male, twenty-eight years of age. The size of the stone was estimated at 3·4 cm., and its actual diameter when removed by Professor Ogston turned out to be 3·2 cm. The apparatus used was a 10-inch spark coil of Apps. During exposure the patient lay on his belly, and a remarkable print of the scrotum appears on the plate. This phenomenon is attributed by Mr. Mackenzie to the moisture of the parts having penetrated the two folds of sateen cloth which covered the plate and moistened the gelatine film so that the cloth slightly adhered to and impressed the film. To obviate similar occurrences, which he had noted more than once, Mr. Mackenzie has since used waterproof paraffined paper for covering the plates. It is open to some question if this interesting phenomenon is quite so easily explained. The rays were directed through the lower pelvic outlet and bladder obliquely on to the plate.

Bones—General Observations.

The following experiment was devised by the author with a view of ascertaining to what particular element of bone the Röntgen ray shadow of bone was due. Three small bones were taken from just above the hoof of a sheep; the first was left in its natural condition, the second decalcified by soaking for several days in dilute hydrochloric acid, and the third calcined in a furnace. The three bones thus prepared were placed side by side on a sensitive plate, and subjected to the rays, with the result reproduced in Fig. 33. The normal bone on the left affords a standard for relative comparison; the centre or decalcified one

* *Bristol Medico-Chirurgical Journal*, March, 1897.

casts a much fainter shadow; and the calcined one on the right yields a photographic record as dark as the normal bone, but sharper and clearer in detail. It should be noted that the process of decalcification was not completely carried out, so that some of the shadow in the centre bone, especially in its lower portion, is doubtless due to lime salts that have not been entirely removed by the acid. This simple experiment seems to show that the main part of the shadow thrown by bone is due to its contained lime salts.

The opacity of bone to the Röntgen rays is much greater than that of the neighbouring soft tissues, a fact doubtless due to the

FIG. 33.—THREE SMALL BONES FROM FOOT OF SHEEP: ON LEFT, NORMAL; IN CENTRE, DECALCIFIED; ON RIGHT, CALCINED (AND CRACKED BY THE HEAT).

earthy matters which form three-fourths of osseous structure. This quality enables us, by means of the 'new photography,' to obtain a sharply-defined shadow of most of the bones of the human body. Where the latter lie in a single layer, and the soft parts around are comparatively thin, as in the hand, a record can be quickly obtained upon either the screen or the sensitive plate. But in the pelvis, where the parts are thick and the bones more or less overlapping, the resulting photograph is obscured. In the case of the head, each half of the skull is more or less recorded on the plate, so that a blurred picture of double

shadows results. For all that, the surface next the plate is always the more sharply recorded, so that indications of the utmost value are often obtainable from skiagrams both of skull and of pelvis.

Bone being relatively opaque to the rays, it follows that any break whether in continuity or in outline, and any abnormal position in relation to joints, will be readily detected by means of the skiagram. As a matter of fact, not only are fractures and dislocations indicated in this way, but also many other pathological states, such as exostosis, caries, altered density, and the formation of callus. The surgeon, indeed, when called upon to deal with injuries and diseases of bone, will find himself furnished with an entirely new weapon of accurate investigation. Instead of long and painful manipulations, often ending in nothing better than a suspended judgment, he will in many instances be able after an appeal to the rays to give a definite diagnosis and prognosis. Such results, it should be noted, may be obtained without causing the patient a moment's additional pain, and without taking off splints (if non-metallic), bandages, or dressings that may have been applied.

It has been surmised by various experimenters that the opacity of bone is due to its contained lime-salts. The skiagram shown in Fig. 33 proves fairly conclusively that the main part of the shadow is thrown in that way.

In order to read his skiagrams aright, the surgeon should make himself familiar with the skiagraphic appearances of bone, both in a healthy and in an abnormal state. A workman's hand, injured many years previously in a machine accident, is portrayed in Fig. 34. The hand, it may perhaps be pointed out, is the right and not the left, as might be at first imagined by anyone unfamiliar with skiagrams. The reason is that the photograph is taken by transmitted and not by reflected light, so that we have on the sensitive plate the record of a shadow, and this is reversed in the process of printing. Owing to non-recognition of this fact by the surgeon the wrong hand is said to have been actually operated upon. Healthy bone appears as a dark shadow with a more or less well-defined outline, and where it is thinner and more spongy, as in the bosses projecting sideways from the distal ends of the metacarpals, and in the small sesamoid bone below

the metacarpo-phalangeal joint of the thumb, the image is fainter. The joints are indicated by clearly-marked light intervals between the bones, where the rays have penetrated the intervening articular cartilages.

As to the abnormal hand, Fig. 34, the reader will do well to study it carefully in detail. The phalanges of the three remaining fingers are enlarged and dark, while the usual gaps between the end joints of the middle and ring digits have disappeared. The most likely reading of these recorded facts is that the fingers have been affected with chronic osteo-arthropathy, which has enlarged the bones and obscured or obliterated some of the joints. As regards pathological conditions, the following appear to be probable:

1. Old greenstick fracture (thumb metacarpal).
2. Mal-united fracture (right angle, second metacarpal).
3. False joint (this may possibly be bony union; third metacarpal).
4. Impacted fracture (bony union, fourth metacarpal shaft).
5. New articulation (fourth metacarpal base).
6. Bony anchylosis (distal end fifth metacarpal and first phalanx of fourth).
7. Fibrous and partially osseous anchylosis (base fourth and fifth metacarpals).
8. Dislocation (multiple, carpus).
9. Compensatory curving of bones (twisted index-finger).
10. Bone hypertrophy (various bones).
11. Obliterated joint (terminal joints second and third fingers).
12. Arrested development of distal epiphysis of first phalanx of middle and ring fingers.

One or two of the above explanations, especially in the absence of a careful examination of the hand itself, are perhaps somewhat open to an alternative reading.

III. FRACTURES AND DISLOCATIONS.

In these injuries of bone, especially when obscure, skiagraphy may often boast brilliant results. For example, it is available when the surrounding parts are too swollen to admit of examination by ordinary methods, or when the manipulations of the surgeon cannot be borne by the patient.

The objection has been made by some surgeons that the rays

Fig. 34.—Injured Right Hand of Workman.
(By Mr. Greenhill.)

reveal nothing that could not be equally well learnt by other methods. To this it may be answered that not a few bone injuries occur in which it is impossible for any man, however skilful, to make an exact diagnosis—at one time, it may be, owing to the swelling and tenderness of parts, and at another to the obscurity of the signs. Under such adverse circumstances precise evidence may be obtainable forthwith from the fluoroscope or the skiagram. Moreover, the gain of this particular form of investigation does not end with recovery. In cases of accident likely to come before a jury, the proof afforded by a photographic record of a bone condition may one day win a civil action, or vindicate the scientific reputation of the medical attendant, two points that will be referred to again under the heading of jurisprudence. Further, if the progress of a fracture be unsatisfactory, the surgeon can hardly be doing his duty either to himself or to his patient if he neglect the possible assistance to be gained from a Röntgen ray photograph. Some medical men scout the idea of calling in the services of a professional photographer to help them in arriving at a diagnosis. If that line of reasoning were sound, it would equally prevent physicians from weighing a patient, because the scaling chair is the work of a professional balance-maker. In a similar way it would preclude them from sending throat secretions to a biological laboratory to be tested for the presence of the diphtheria bacillus, or from using the microscope, the stethoscope, the phonendoscope, and the rest of the hundred and one aids to accurate investigation sold by the instrument-makers.

To sum up: in dealing with bone injuries successful skiagraphy, compared with previous methods, offers the following advantages: It substitutes speed, accuracy, and finality for delay and doubt; it affords exact evidence that may suggest, confirm or modify the diagnosis of the surgeon; it may furnish both grounds for prognosis and hints for treatment; it may save the patient the pain of useless, and perhaps dangerous, manipulations, as well as the shock of anæsthetics; it provides a permanent record of the precise nature of an injury; it may prove a safeguard for the patient and for his medical attendant, both in the present and the future; lastly, it can hardly fail to be of value for teaching purposes.

It seems likely that the Röntgen rays will help towards a truer

conception of what really takes place in some particular injuries, such as Colles' of the lower end of the radius (see Figs. 36, 37, 38).

Of late a good deal has been heard of the practice of wiring recent fractures, such as those of the olecranon, lower end of radius, patella, and of other bony parts where union is commonly delayed or vicious. Under the conditions of modern surgery the plan appears to offer in many cases a good prospect of securing firm and rapid union. It need hardly be added that the procedure consists in cutting down under antiseptic precautions upon the broken ends, which are then drilled obliquely and brought together by stout wire. In this particular class of cases the surgeon will learn from the rays—(1) whether wiring is advisable, (2) whether proper apposition has been secured, (3) whether bony union has followed.

Where a fracture is attended by such complications as impaction, comminution, multiplicity, interposed tissues, extension into a joint, or dislocation, the skiagraph may obviously afford most useful information. The practical value of the method, however, extends beyond diagnosis, for by further investigation it can be ascertained whether the bones have been reduced to proper position, and whether sound union has followed.

Where a fracture has ended in fibrous union, false joint, or other imperfect result, the exact state of affairs can, with one or two exceptions, be readily found out by the skiagram. A similar remark applies to a stiff joint after dislocation or other injury. In all these cases important indications may be gained as to the appropriate form of treatment, whether by resection, osteotomy, wiring, refracture, or the breaking down of adhesions. The diagnostic application of the rays, it may be observed, is likely to do away with much of the time-honoured business of the bone-setters. As Mr. Howard Marsh and others have pointed out, the greatest successes of those irregular practitioners have been scored in nine cases out of ten by the forcible rupturing of arthritic bands. It is now open to everyone to put to an absolute test by means of Röntgen rays a bone-setter's assertion as to the existence of a fracture or a dislocation. In this unexpected way, it is interesting to note, science has cut away the ground from under the feet of the charlatan. Professor Röntgen's discovery has dealt the bone-setter a deadly blow that ages of scientific protest have failed to accomplish.

FIG. 35.—FRACTURE OF HUMERUS UNITED WITH A FORWARD V-SHAPED BEND.
(By Mr. Gerard Peek, Scarborough.) Natural size.

(In taking the original of the above block, the apparatus broke down after two minutes' exposure. The picture, however, proves how a readable record can sometimes be procured under adverse circumstances.)

A curious condition of affairs is shown in Fig. 35. The original was taken by Mr. Gerard Peck, of Scarborough, and kindly placed at the writer's disposal. The patient was a woman sixty-two years of age, who injured her arm by a fall. Pain was felt at the time, but curiously enough the fracture was not detected for some months. The patient was dressed by her daughter, and is reported not to have noticed the deformity until she one day saw it reflected in a mirror.

The photograph was taken with a Tesla set capable of giving a 2-inch spark, and an exposure of two minutes. It reveals a fracture of the lower end of the forearm, united at an extreme angle, with a v-shaped forward bend.

An instance of the value of the diagnosis of adhesions is afforded by the case of a patient who suffered from a locked wrist, and the skiagram showed there was no disease of bones. This result pointed by a process of exclusion to the presence of inter-articular bands, and indicated a successful line of treatment.

Special Fractures.

Fractures of the scapula that may be detected by ordinary manipulation need not be considered here. Sometimes, however, an injury of the kind is exceedingly obscure, in which case a skiagram might disclose its real nature. For instance, it would be difficult or impossible in any other way to diagnose the rare fracture of the glenoid cavity, especially when impacted or when complicated by dislocation.

Fractures of the collar-bone can be readily shown by the rays, but as a rule there is little information to be gained in that way that could not be acquired by simpler methods of examination. An exception may perhaps be made in the case of the break without displacement that sometimes occurs in the portion of bone which is attached to the conoid and the trapezoid ligaments. Such a case was reported by Dr. Richardson :* ‘A football-player of nineteen injured his left shoulder. Six hours after the accident tenderness was found at the outer end of the clavicle, but neither crepitus nor deformity was to be made out. The Röntgen rays showed a solution of continuity at the point of tenderness, where a week later callus appeared.’

* *Boston Medical News* of December 26, 1896.

Fractures about the elbow are often attended with such rapid swelling that, unless seen at once, it is in many instances impossible for several days to ascertain the extent of the injury. Indeed, it is hardly too much to say that under such circumstances a skiagram of the swollen elbow is absolutely the only means of exact diagnosis at the command of the surgeon, who may in this way save much valuable time and anxiety. For instance, the damage may be of such a kind as to demand prompt excision. In any event, the skiagraph will probably indicate whether the line of fracture is (*a*) transverse, (*b*) T-shaped, (*c*) through condyles, (*d*) through epiphyses; and whether complicated by (*e*) dislocation or (*f*) fracture of the olecranon. In this way the surgeon can inform the patient forthwith as to the probable duration and result of treatment. Moreover, from the knowledge gained as to whether the fracture is extra- or intra-capsular, he will know exactly when to begin and when to avoid early passive movements. Thus, if the break be transverse, above the capsule, such exercise can be delayed for a month or more, 'as there is then no danger of a stiff joint, but a risk of the passive movements at the seat of fracture leading to a false joint' (Walsham). Indeed, the advantages of the skiagraph to the practical surgeon are nowhere more apparent than in obscure injuries to the elbow-joint.

Fractures of the forearm do not require much notice in their relation to skiagraphy. They are readily accessible to the rays, the information from which may be applied upon general principles. However, so far as the pathology of fracture of the lower end of the radius is concerned, the method has already demonstrated a number of fresh facts. Mr. Lynn Thomas, of Cardiff,* published the interesting and instructive case of a patient who had sustained a double Colles' fracture. From a clinical point of view the lesion appeared to be identical on both sides, but the skiagrams showed a wide difference in the bone injuries. In each the styloid process of the ulna was fractured at its base, an event usually described by surgical authorities as somewhat rare. One wrist (Fig. 36) showed the ordinary fracture of the lower end of the radius, with outward displacement; the other (Fig. 37), slight impaction of the radius about three-quarters of an inch from its lower end, to be detected by

* *British Medical Journal* of January 2, 1897.

Fig. 36.—Double Colles' Fracture showing Ordinary Fracture of Radius with Outward Displacement, and of Styloid Process of Ulna.

(Mr. Lynn Thomas.) Natural size ; see also Fig. 37.

Fig. 37.—Double Colles' Fracture showing Longitudinal Fracture of Radius with Slight Impaction, and Fracture of Styloid Process of Ulna.

(Mr. Lynn Thomas, F.R.C.S.) See also Fig. 36.

noticing the irregularity on the ulnar side of the bone. By the side of, and near that projection is a 'complete longitudinal single fracture of the lower end of the radius, showing a detached portion of a triangular shape in its normal position attached to the radio-ulnar ligament.' In a later communication to the same journal, Mr. Thomas expressed an opinion that 'the true pathology of one of the commonest of fractures (*i.e.*, Colles') requires rewriting in the leading surgical text-books in the English language.'

FIG. 38.—COLLES' FRACTURE, WITH RUPTURE OF RADIO-ULNAR LIGAMENT. (Mr. Lynn Thomas.)

Mr. Thomas has placed a third skiagram (Fig. 38) at the disposal of the writer. In his opinion, this illustrates the rupture of the radio-ulnar ligament described by Mr. Clement Lucas in Guy's Hospital Reports for 1888.

The illustrations shown in Figs. 39 and 40 furnish a good example both of fractured forearm and also of the service that the Röntgen rays can at times afford in surgical practice. They were taken from a restless and muscular young man, eighteen years of age, under the

care of Mr. Jonathan Hutchinson, junior, at the London Hospital. The patient presented himself with a broken arm, which had been put up in splints a few days before at another institution, and which he imagined was not going on well. A skiagram, not here reproduced, proved that there was double fracture, and that both bones were in perfect alignment. When he returned a week later, the rays revealed considerable displacement (Fig. 39).* The broken bones were thereupon readjusted, but at the end of

FIG. 39.—DOUBLE FRACTURE OF FOREARM, SHOWING DISPLACEMENT; GRAIN OF WOODEN SPLINT PLAINLY SHOWN.

(By Mr. Greenhill.) Five in. Apps coil; 15 in. dist.; 3 min. ex.

another week the fragments were again found to be over-riding (Fig. 40). The limb was reset, and ten days later the skiagram recorded union in good position, almost but not quite equal to that demonstrated in the first photograph. The two interesting pictures of the series here shown were taken with an Apps coil,

* The photographs were taken through splints and clothing. In the first the grain of the wooden splint can be traced.

three minutes' exposure, 5-inch spark, 15 inches' distance, by Mr. Greenhill.

In the after-treatment of a restless patient, then, the skiagraph is likely to prove of constant value. Even if the results of such an examination be negative, no harm will have been done, as it can be conducted without taking off a single splint, dressing, or garment. By availing himself of its aid, the surgeon may possibly

FIG. 40.—DOUBLE FRACTURE OF FOREARM, SHOWING DISPLACEMENT. The dark shadow athwart the lower fragments is due to adhesive plaster. (Mr. Greenhill.)

avoid consequences dangerous alike to the welfare of his patient and to his own reputation.

Fractures of the hand can be readily demonstrated by means of the Röntgen rays. A break of the fourth metacarpal, not an uncommon injury, is sometimes difficult to diagnose by ordinary methods, but would be at once evident to the skiagrapher.

The illustration portrayed in Fig. 41 shows the results of a cogwheel accident fourteen years previously. The metacarpal

bone of the forefinger has been apparently broken into two main pieces, which lie at a cross-angle of about thirty degrees. The irregular shape of the lower fragment probably results from chronic periostitis and osteitis following the injury. Between the two fragments there appears to be a kind of false joint. The middle joint of the fore-finger is partly obliterated by what seems like bony union. The sesamoid bone opposite the distal end of the thumb metacarpal has apparently become united to the latter by a more or less ossified ligament. The original photograph, kindly lent to the writer by Dr. J. W. Philpots, of Parkstone, shows unmistakable traces of muscles and other soft structures. Thus, in the outer side of the little finger metacarpal may be traced the abductor and flexor brevis muscles. On the outer side of the middle joints of the second and third fingers are what appear to be the lateral expansions of the common extensor of the digits. Along the back of the bones of the metacarpal and phalanges of the thumb the extensor tendons can be clearly traced. The tendon of the extensor secundi internodii, indeed, can be followed up to its insertion at the base of the terminal phalanx. Unfortunately, most of these results are lost in reproduction.

In fractures about the pelvis the Röntgen rays, so far as one can judge, are not likely to help the surgeon much. The hip, again, is deeply placed, and so far satisfactory results are not always attainable. However, much is often to be learnt in the case of children and young adults. It will be wise to try and secure a record of impacted intracapsular fracture of the hip, because of its frequent after-shortening, which may be attributed by patients to unskilful treatment.

In extracapsular fracture of the hip the rays may show conclusively whether the head of the bone is impacted or not in the great trochanter, especially when a comparison is made with a photograph of the sound side. The knowledge thus gained, whether negative or positive, could not fail to be helpful to treatment, inasmuch as extension is contra-indicated in the impacted variety. Moreover, it would guide the prognosis as to permanent shortening and stiffness of the joint. Generally speaking, a fracture can be readily enough demonstrated by the skiagraph in all parts below the hip.

In fractures of the shaft of the femur the value of the

Fig. 41.—Hand Showing Old Standing Fracture of Metacarpal Bone. Result of Cogwheel Accident.

Somewhat reduced. Dr. J. W. Philpot's case.

Fig. 42.—Rare Spiral Fracture of Tibia.
(Dr. Taft's case.)

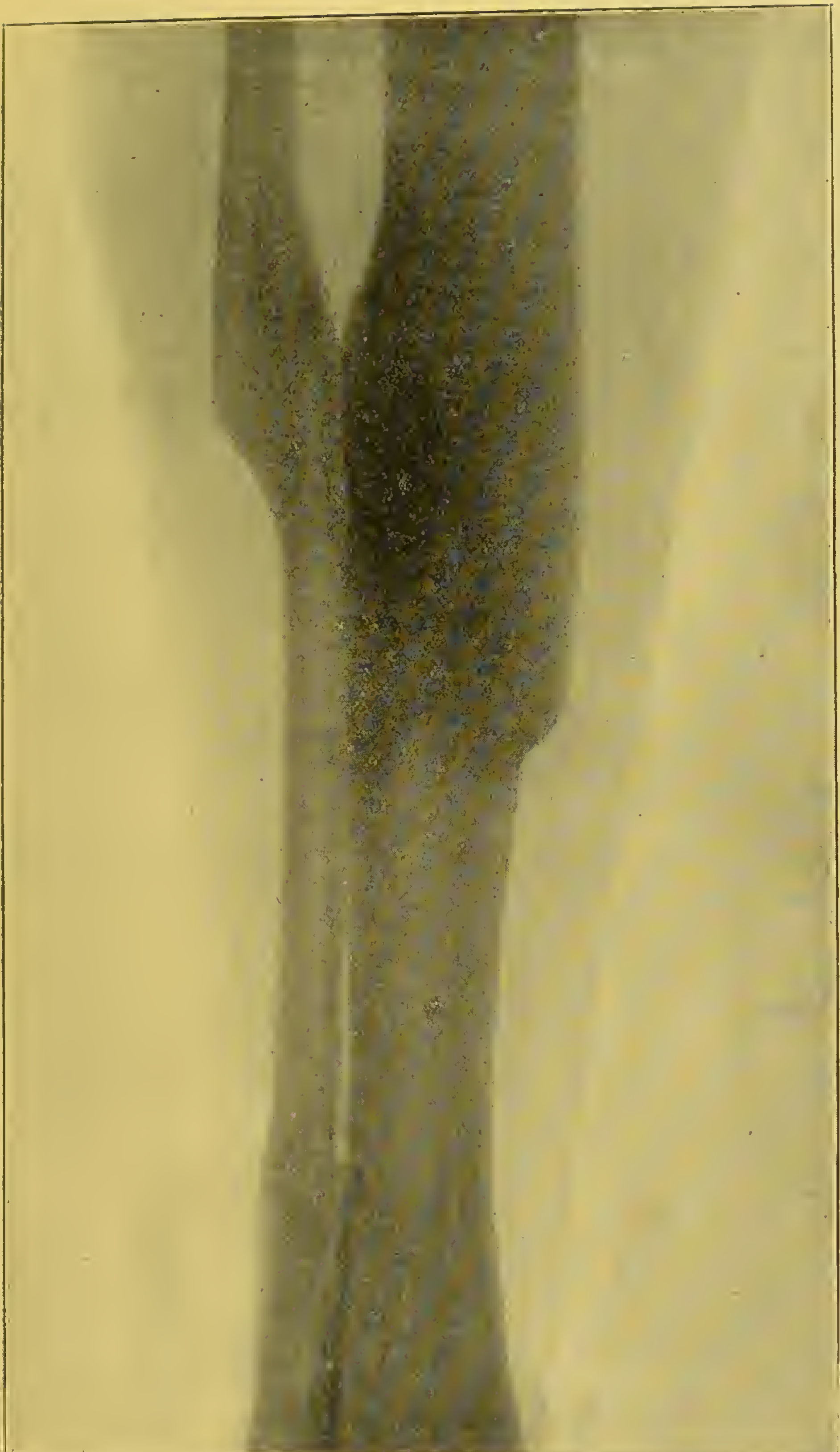


Fig. 43.—Fracture of Tibia and Fibula: Three Months after Injury; no Outward Deformity.

(Dr. Low's case.)

skiagraph will lie chiefly in its evidence as to the proper setting and subsequent union of the broken ends.

In fractures of the lower end of the thigh-bone the skiagraph is likely to be more useful. Injuries about the knee are apt to cause rapid swelling in and around the joint, so that a thorough examination by ordinary methods is out of the question. Then it is that a confident appeal may be made to the Röntgen rays. Without taking off a splint or dressing, we may expect to ascertain one or more of the following conditions: (*a*) line of fracture, whether oblique, transverse, T-shaped; (*b*) implication or otherwise of joint; (*c*) separation of epiphysis.

Fracture of Patella.—Unless the patient be seen at once after this accident, the parts often become so swollen that it is impossible to diagnose the nature of the injury. For the investigation of such a case the Röntgen rays are specially adapted. They will reveal not only complete, but also incomplete, fractures —that is to say, where the starred or fissured fragments are kept in position by the aponeurosis. As regards after-treatment, the surgeon will be able by means of a skiagram to determine whether his methods have brought the patellar fragments into good position. Here, too, the results of wiring can be closely followed.

In fractures of the leg, when either the tibia or the fibula is alone broken, the diagnosis, as every practical surgeon knows, is often extremely difficult. Indeed, if there be much swelling, it is in many instances impossible to determine whether the injury is a fracture or merely a sprain. Any such doubt, however, could be speedily cleared away by the skiagraph. The most conservative of surgeons will hardly deny that the ability to settle such a point must constitute a solid advance in practice.

When both bones of the leg are broken, the diagnosis is usually so clear that there would be no need to appeal for confirmation to the skiagraph. Nevertheless, the method may be of use in other directions, and at later stages of the treatment.

A rare spiral fracture of the tibia was discovered skiagraphically by Dr. Taft,* and by the kindness of that gentleman is reproduced in Fig. 42. It is instructive to learn that the sensitive plate yielded a clear and unmistakable record of the fracture, which, nevertheless, could not be seen by the aid of Edison's

* *Boston Med. and Surg. Reporter*, February 25, 1897.

fluoroscope. Dr. Taft accounted for this failure by the difficulty of getting the screen sufficiently near the bone on account of the splints and pads, as well as the swelling of adjacent parts. A second skiagram, taken from the side, showed that the fracture ran up the tibia in a spiral fashion for a further distance about equal to that shown in the figure.

Another unusual fracture of tibia was reported by Mr. Hatch, of Johannesburg.* There was $1\frac{1}{2}$ inches of shortening, together with stiffness and deformity. A skiagram showed that the main fracture was transverse below the head of the tibia, with impaction of the lower fragment. The head of the fibula was thrust up, and carried with it the broken-off external tuberosity of the tibia.

By no available means of investigation other than the Röntgen rays could the exact nature of the two foregoing fractures have been ascertained in the living subject. There can be little doubt that, as cases accumulate, many hitherto unsuspected forms and combinations of fractures will be recorded.

The double fracture of the leg shown in Fig. 43 is from a skiagram kindly placed at the disposal of the writer by Dr. F. H. Low, of West Kensington. The patient was a medical student of about twenty-two or twenty-three years of age. His leg was put up in splints in the ordinary way, and he was kept in bed for nine weeks. A skiagram of his injured leg, taken three months after the accident, revealed the state of affairs to be seen in the picture. The lower fragments appear to have been thrust upwards between the upper, a condition which the medical attendant supposed to be due to the fact that the patient had used the limb before the bones were firmly consolidated. In the light of numerous other observations, however, it would appear that such irregular union is the rule rather than the exception. A further point of general interest is that, in spite of the apparent extent of the deformity, careful measurement showed only $\frac{1}{8}$ inch of shortening in the whole limb. No noticeable alteration was caused in the gait, probably because there was some compensatory depression of the pelvis on the injured side.

As to fractures of the lower end of the bones of the leg, it seems likely that the pathology of Potts' fracture, like that of

* *St. Mary's Hospital Gazette* for March, 1897.

FIG. 44.—FRACTURE OF LOWER END OF FIBULA, WITH DISLOCATION OF ANKLE JOINT.

(Mackenzie Davidson, M.B.)

Colles' of the radius, will have to be re-written in view of the fresh facts gleaned from its study by the Röntgen rays. An excellent illustration of such a fracture, with dislocation, is shown in Fig. 44, of which the original was kindly lent to the writer by Mr. Mackenzie Davidson, M.B.

Fractures of the foot require little notice in connection with skiagraphy. Tarsal and metatarsal fractures are often obscure, and are no doubt at times treated as sprains. An interesting case of this kind brought under the notice of the writer was that of a young lady whose foot was injured by a fall from a bicycle. Some six weeks later, as the foot was still painful, it was skiagraphed, with the result that an unsuspected metacarpal fracture was at once revealed.

Fractures about the Head.

Fractured skull may be readily shown by the skiagraph when situated upon the face or the cranium—that is to say, anywhere except at the base of the skull. In the lower jaw fractures can be readily demonstrated by using the method described for taking teeth (p. 99).

Fractures of the ribs, which are now and then difficult to detect, may be diagnosed by the skiagraph. In some instances —as, for example, in lunatic asylums—the proof of such injuries may have a medico-legal interest. Indeed, it may be mentioned in passing that the rays are likely to be of special service to the surgeon when called upon to diagnose injuries of lunatics, mutes, infants, and other folk who are from any reason unable to furnish good personal evidence of their subjective symptoms.

Fractures of the vertebræ, from the nature of the case, usually present little difficulty in the way of diagnosis. There are, however, instances on record of unsuspected partial fractures of the vertebræ which have been converted into complete ones by some movement, voluntary or involuntary, on the part of the patient. Thus, a patient has been known suddenly to break off the odontoid process of the axis by nodding his head. Another, again, suffering from obscure cervical injury, has been suspected of malingering, and roughly shaken up, with fatal results. In doubtful injuries of the neck and spine, therefore, it would be advisable, wherever possible, to obtain a skiagraphic view. In

the neck this is comparatively easy, and no doubt in the process of time equally good results will be obtained lower down the spinal column. Lastly, if fractures of the spine could be exactly located by the rays, the feasibility of such surgical methods as 'wiring' might possibly be considered by the surgeon.

This section may be concluded by quoting some important practical conclusions arrived at by two surgeons, one in Germany and the other in America. For some months both made a routine practice of examining with the Röntgen rays every fracture brought under their notice.

The chief point insisted upon by Dr. Richardson, of Boston, is that both in recent and in united stages malposition of broken ends is common, although not revealed by any previously known method of examination. He mentions a number of cases where the position was absolutely perfect so far as could be ascertained by ordinary means, but in which, nevertheless, a Röntgen ray photograph showed considerable displacement.

Oberst, of Halle, finds that without the aid of anæsthetics and without handling the parts he can make an exact diagnosis as to the position, the nature, and the direction of fractures. He thus avoids the danger of laceration of vessels and of other structures that attends manipulation of the fragments. Ether he now reserves for painful reductions. He also makes a practice of taking a skiagram at the end of treatment. His main conclusions are as follows:

1. The ideal or perfect union is rare.
2. In all oblique fractures there is more or less overriding of the broken ends.
3. In bones that are deeply seated considerable deformities may escape notice.
4. In cases followed by long-continued functional disturbances, the Röntgen rays invariably showed overriding of fragments to a greater or less extent, when manual examination revealed no deformity.

Dislocations.

In this class of injury the surgeon will usually arrive at an absolute diagnosis by ordinary methods.

A dislocation may be examined with advantage when the parts are too swollen and painful to admit of manipulation. When

Fig. 45.—Backward Dislocation of Bones of Forearm in a Child.

Fig. 46.—Pelvis, showing Rickety Distortion of Neck of Thigh-bones. (Dr. Routh's case.)

8

complicated with fracture, the value of the new method can hardly be over-estimated for the ease with which a difficult diagnosis may be reduced to a certainty. To take a concrete instance, let us suppose a dislocation of the elbow to be examined by the skiagraph, which may demonstrate any of the following among other complicating fractures—(1) of the coronoid, (2) of the olecranon, (3) of the neck of the radius, (4) of lower end of humerus, (5) of condyles of humerus, (6) through epiphysis of humerus. The importance of trustworthy evidence on any of these points must be clear, when one considers to what an extent such knowledge must modify diagnosis, prognosis, and treatment. The illustration of backward elbow dislocation of both bones of the forearm in a child shown in Fig. 45 is from a skiagram taken by Mackenzie Davidson.

The backward dislocation of the first phalanx of the thumb upon the metacarpal has always been a matter of surgical interest, chiefly because of the difficulty often experienced in replacing the bones. It is interesting to note that the rays have confirmed the anatomical theory advanced many years ago by the late Sir George Humphrey, that the hindrance was due to the sesamoid bones being carried back with the phalanx, and held there between the separated articular surfaces by the flexor brevis pollicis.

In old-standing dislocations the new photography is likely to be of service. For instance, it will enable the surgeon to ascertain the precise condition of affairs at the seat of injury, so that his subsequent treatment shall be founded upon exact data. Thus, if the skiagraph showed a fresh articulation to have been formed in an old-standing dislocation of the shoulder, the surgeon would not make any attempt at reduction, except under most exceptional circumstances.

Congenital dislocations of the hip can be well shown in children.

The accompanying illustration (Fig. 46) from a case of Dr. Routh's, taken by Mr. Greenhill, shows a suspected congenital double dislocation to be really a rickety bending of the angles of the thigh bones.

IV. DISEASES OF BONE.

As bone casts a definite shadow under the Röntgen rays (when not obscured by the mass of surrounding tissues), it follows that bony outgrowths will do the same. In this way one can get a good skiagraphic record of osseous thickenings and exostoses. An outstanding enchondroma, when it consists of pure cartilage, will throw a faint shadow with a short exposure. As the growth, however, becomes ossified, it gives rise to a denser tracing on the sensitive plate. Subperiosteal thickenings, as in syphilis, may be readily demonstrated by means of a skiagram, and also the hyperplastic conditions met with in rickets and in Charcot's disease.

FIG. 47.—OSSIFYING ENCHONDROMA OF FINGER, OF OLD STANDING: FOLLOWING INJURY.

(Messrs. Allen and Hanbury.)

A good example of ossifying enchondroma has been kindly furnished to the writer by Messrs. Allen and Hanbury, of London. It was taken from a man of about fifty who had sustained an injury to the hand many years previously. On being skiagraphed, the tumour presented the appearance shown in Fig. 47. From its generally light shade, we may assume it to be composed either of spongy bone or of cartilage that has undergone partial ossification, the areas of the latter being shown by darker mottlings. An interesting point is that the form of the growth is distinctly traceable where it overlies the darker phalanx. This lighter colour may be

due to its replacing the compact phalangeal tissue by new spongy bone. A somewhat similar appearance is to be found in Fig. 19, where absorption of the outer shell of the bone has followed the impact of a bullet. As already remarked, the record of spongy bones, such as the sesamoid, is comparatively faint in comparison with that of the medullated bones, an appearance that may be due to the relatively less amount of lime salts present. This difference is well shown in the pelvis, where the sacrum, a light spongy bone, appears faint by contrast with the deep shadows of the solid and compact iliac bones. Another observation that appears to bear upon this point is that of M. Potain, who recently reported to the Paris Academy of Sciences the occurrence of light spots on the skiagrams of gouty bones. These translucent spots, he thought, were due, not to a thinning or rarefaction of the osseous tissue, but to the presence of tophi projecting from the bone.* Presumably, the compact tissue is wanting at the point of projection.

This gouty translucency, if such a term may be applied, was explained by M. Potain in the following ingenious and suggestive manner: 'The change appears to be due to the substitution of urates for phosphates of lime. Comparing the different salts which enter into the composition of bone, they are found to be differently permeable to the Röntgen rays. Phosphate and carbonate of lime and chloride of sodium are little permeable, soda and magnesia more so, and urate of lime still more. By making use of two cardboard boxes, the one filled with urate of lime and the other with tribasic phosphate, and submitting them simultaneously to radiography, it is easy to ascertain that the urate of lime is eight times more transparent than the phosphate, because a precisely similar shade is only to be found where the thickness of the latter is eight times less than that of the former.'

In gouty bones, then, M. Potain concluded that the points where urates are substituted for phosphates become more transparent to the Röntgen rays. He further stated that the osseous thickenings due to chronic rheumatism or rheumatoid changes had an increased opacity. If these observations be correct, it follows that it is possible by means of the skiagraph to distinguish whether bony enlargements are the result of gouty or of rheumatoid changes. Assuming that the latter enlargements are more

* *Medical Press and Circular*, March 10, 1897 (p. 249).

opaque, that condition must be carefully distinguished from the general atrophic state of the bones mentioned when discussing the hand affected with chronic rheumatoid arthritis, shown below in Fig. 48.

M. Potain has made the following practical application of his conclusions: 'In subjects affected with nodosities of Heberden, a lesion of which the gouty nature is still a debated question, very distinct transparent spots are found at the level of the phalanges, which appear to decide the dispute in favour of those who consider gout the primary origin of the affection.'

As regards the outlines of bones, then, the Röntgen rays may be expected to be useful in the hypertrophies due to syphilis, enchondroma, rickets, gout, and rheumatism, and also in the important class of subperiosteal thickenings. The opacity of the rheumatoid peri-articular deposit is often well shown in a stiff ankle, while the opposite or general atrophic condition in the same disease is conspicuous in the accompanying skiagram, kindly placed at the disposal of the writer by Dr. J. R. Philpots (Fig. 48).

The subject of the photograph was a lady, aged thirty-one, who had suffered from the disease since the age of thirteen. Her father and mother both suffered from rheumatism, and a sister from rheumatoid arthritis. Her lower extremities were first affected, but later almost every joint of the body has been invaded, and some permanently stiffened.

On comparing the bones shown in this skiagram with those of a healthy hand, a marked difference will be at once detected. The rheumatoid bones look more fragile; in point of fact, they are atrophied, a condition which renders them more penetrable to the rays. Indeed, from their appearance, it may be pretty safely inferred that they are deficient in bone salts. Their outline is sharper and darker than normal, and their substance lighter. Their relatively small size—that is, for a person of that age—is doubtless due to the arrest of development from early disturbed nutrition. Their greater transparency can be best seen in the fifth metacarpal, whereas the darker look of other bones is most likely owing to the greater amount of tissue to be penetrated on account of the clawed-up hand. It will also be noticed that the bosses of ossified peri-articular cartilage on the phalanges are much of the same shade as the body of the bone. All the fingers are dislocated from the metacarpals. The base of the first phalanx of the

Fig. 48.—Hand Deformed by Chronic Rheumatoid Arthritis.
(Somewhat reduced. Dr. J. R. Philpot's case.)

fore-finger is apparently fixed against the distal ends of the second and third metacarpals, but the bases of the middle and third fingers appear to be partly wedged between the third and fourth and the fourth and fifth metacarpal heads respectively. The plate shows how a skiagraph will afford anatomical data for the explanation of such deformities. At the same time, however, it should be borne in mind that the proper reading of the facts of the skiagram is by no means always an easy matter. Lastly, it may be pointed out that the shadow of the thumb confuses the radial half of the figure.

Mr. Espin, of Newcastle, has noted a similar transparency in the bones of tuberculous subjects. In one case—that of a youth of sixteen, with a locked wrist following injury—he found 'the bones of the carpus ill-defined, and the ulna and radius, metacarpal bones and phalanges, abnormally transparent.' The transparency was in marked contrast with the appearance of the bones of the other wrist. His second case was that of a young man whose radius had been previously removed for tubercular disease, and who had also suffered from a tubercular abscess. On examination, he found that all the bones of both arms and legs showed an abnormal transparency.

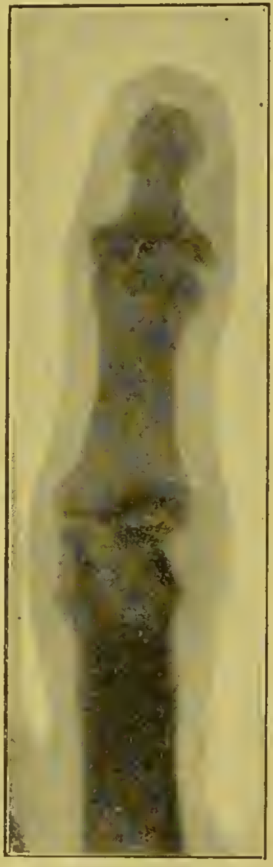


Fig. 49.—Finger of Cricketer, Showing Absorption of Bone and Fibrous Adhesions of Joint.

It seems probable that transparency, denoting malnutrition or atrophic changes, might be expected in such maladies as rheumatoid arthritis, osteomalacia, tubercle, and cancer, and also in the course of senile decay.

Another instance of absorption of bone, apparently after abscess, is the following: The patient, a healthy man, about thirty years of age, was struck by a cricket-ball at the end of the right ring-finger, which was painful and swollen for several months, and ultimately became stiff. Except for some awkwardness in writing,

he suffered little inconvenience from the resulting deformity. Upon presenting himself at a Metropolitan hospital a skiagram was taken, which clearly showed osseous union at the terminal joint of the affected finger, while the base of the second phalanx was hollowed out, apparently as the result of an abscess. From the view here given (Fig. 49) it can be inferred that any union between the radial half of the joint surfaces is certainly fibrous, while that on the ulnar side is probably of the same nature.

Caries of Bone.

Mr. Noble Smith* published an interesting case in which disease of the cervical spine was revealed by the skiagraph. Various diagnoses had been made of the patient's condition, as, for example, hysteria. The Röntgen photograph, however, disclosed an irregular mass of bone replacing the upper four vertebræ of the neck. This evidence proved the existence of a severe lesion that had undergone extensive repair. Not only did it clear up the diagnosis of an obscure case, but it also yielded important indications for future treatment.

In another case recorded by the same surgeon, a provisional diagnosis of caries of the cervical vertebræ had been suggested by the presence of torticollis and other signs and symptoms. However, the skiagraph showed conclusively that the spine was not affected. This negative result warranted alternative positive conclusions as to the nature of the malady.

In some instances osteo-myelitis may be demonstrated by the rays. However, as pointed out by Geisler, the rarefactive change is in the majority of cases obscured by the shadow of the overlying necrotic layer.

The bone changes of osteo-arthritis were well illustrated by a case reported to the Paris Académie des Sciences by Professor Lannelongue.† A patient at the Hôpital Trousseau had been affected for several years with an osteo-arthritis of the knee-joint, which was anchylosed in an extended position. The diagnosis was fully confirmed by a skiagram, which showed hypertrophy of the lower end of the femur, together with atrophy of the upper epiphysis of the tibia. Between the two bones a light interval proved the absence of bony union.

* *British Medical Journal*, 1896.

† Paris Thèse, No. 58, D. 23, Louis Laurent.

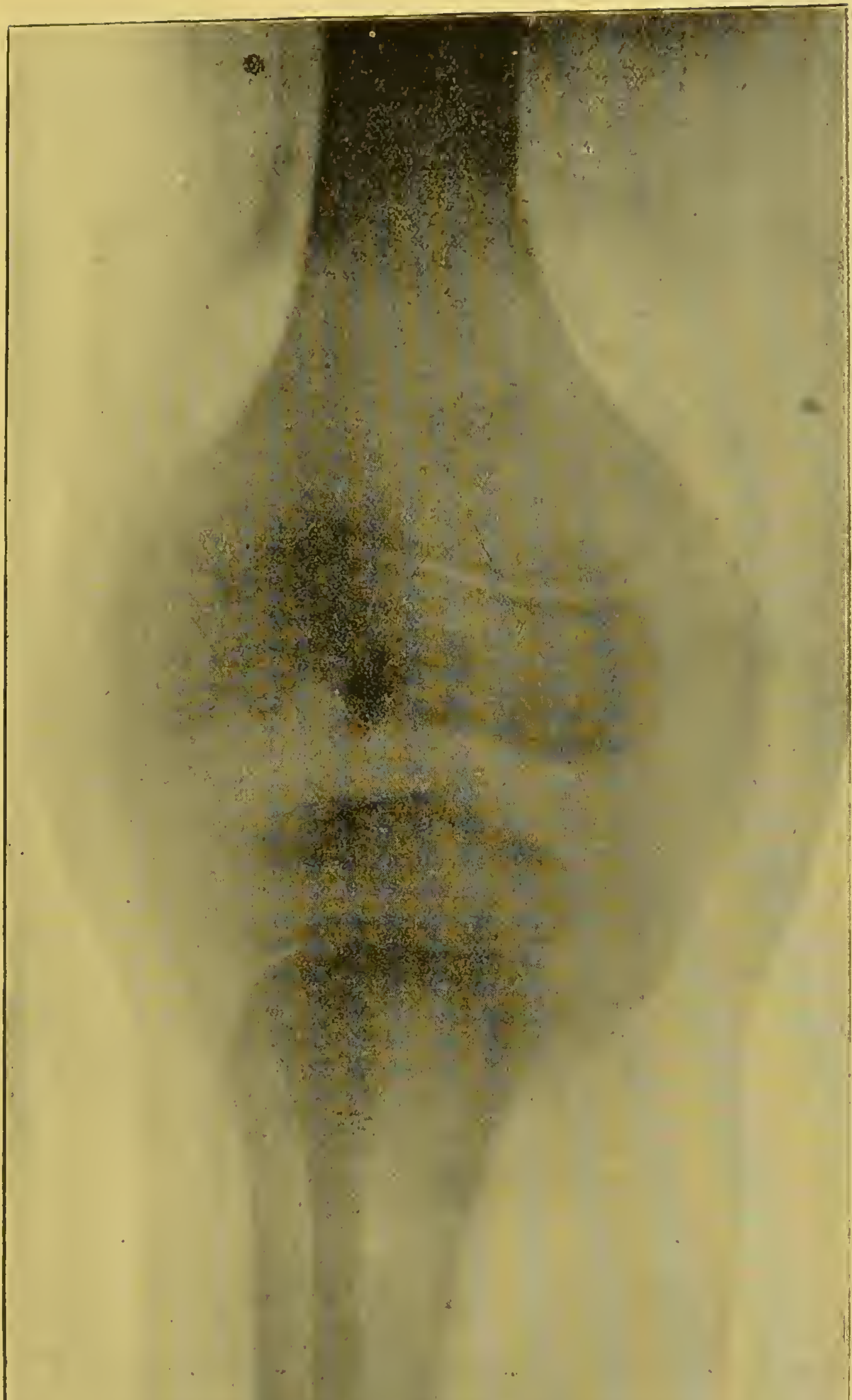


Fig. 50.—Knee-joint showing Erosion of Cartilage of Femoral Epiphysis: Shaft of Femur Healthy.

(Lynn Thomas.)

Fig. 50 shows a case kindly furnished by Mr. Lynn Thomas. The conditions of the knee joint probably resulted from a former tubercular synovitis. There is extensive erosion of the tubercular surface of the femoral epiphysis, while the diaphysis is apparently healthy.

In a stiff joint, bony anchylosis usually shows under the rays as a continuity of dark bone structure that is unmistakable. On the other hand, fibrous union, as we have seen, is inferred from the negative evidence of a light interval between the articular surfaces. Dr. Joachimsthal,* of Berlin, mentions a case in which a boy of sixteen had the knee excised. The site of the operation was skiagraphed eighteen years later, when the bones of the leg and thigh were seen to be welded together into one solid bone, bent at an obtuse angle. The compact tissue at the edges and the bars of the cancellous tissue both showed a perfect continuity. This adaptation afforded a good example of the change of structure and form that may follow altered function.

New growths in the substance of bone may at times be photographed by the Röntgen rays. The first case of the kind was recorded by König, who found a bright spot, with dark contour, the size of a shilling, in the upper part of the tibia to be due to sarcoma.

Dr. Richardson, of Philadelphia, says that by the aid of the fluoroscope he has been able to watch the growth of an osteo-sarcoma of the radius from day to day. His case is thus described :

'General W., aged fifty-nine, had suffered for twelve months from a painful swelling of the right wrist. By means of the fluoroscope, the ulna was seen to be intact, the radius to terminate abruptly in the faint shadow of a carpal tumour. A thin shell of the radius could be seen remaining. The diagnosis of osteo-sarcoma of the radius, made from the history of the case and from inspection and digital examination, was practically proved by the fluoroscope and the skiagram. A previous consultant had assured this patient that the tumour was an aneurism of the radial artery. In a second skiagram, taken a month later, the shell of bone had entirely disappeared—a fact that demonstrated the bony origin of the tumour and the rapidity of its extension. The arm was amputated, and the disease proved to be an osteo-sarcoma of the radius.'†

* *Therapeutische Monats.*, *Lancet*, February, 1897.
† *New York Medical News*, December 19, 1896.

Dr. Richardson, of Boston, has reported a case in which exploration of a tumour in the upper jaw of a woman of fifty-one revealed a sequestrum. Subsequent operation brought to light further extensive necrosis.

V. CONGENITAL AND OTHER DEFORMITIES.

The underlying bone conditions of many deformities of the human body can be clearly demonstrated by means of the rays. This fact has been brought out by Mr. Barwell in a series of articles. He remarked that hitherto it has been possible to study such deformities only after death, and upon the dry bone, but that now skiagraphy has made it feasible to ascertain the actual conditions upon the living body, during the continuance of muscular and fascial tension.

It may be laid down as a general law, with regard to such deformities, that the Röntgen rays confer upon the surgeon the power of doing, with pretty accurate precision, what he has hitherto been able to do but tentatively—namely, to plan beforehand the mode and extent of his osseous operation. An excellent example of this general statement will be seen in the accompanying illustration (Fig. 51), reproduced by permission of the *Lancet*. Mr. Barwell says of it: 'The reader will perceive that the *x*-rays have marked out an abnormal length and a downward bend of the neck of the astragalus as being the obstacle to the restoration of proper form to the tarsal arch.' Fig. 51A, also from the *Lancet*, gives an excellent illustration of a healthy foot bent strongly downwards.

In deformities of the spine, the rays will often afford valuable information. This is all the more likely now that operations in that region are becoming matters of everyday surgery. A good instance of the diagnostic value of the rays in cervical cases has been already mentioned under the section on Diseases of Bone (p. 92).

Numerous cases of polydactylism and allied congenital deformities have been published. In one or two instances the skiagraph has indicated the appropriate line of operation upon supernumerary fingers and toes.

The writer appends an interesting example of polydactylism.

* 'On Various Forms of Talipes as depicted by the *X*-Rays,' *Lancet*, 1896.

Fig. 51.—Talipes Equinus in a Young Man of nineteen: Deformity began at three years of age.

(Taken by Mr. Sydney Rowland. Mr. Barwell's case.)

FIG. 51A.—A NORMAL FOOT BENT STRONGLY DOWNWARDS. COMPARE WITH PRECEDING FIGURE.

The case was kindly placed at his disposal by Dr. Milne, the medical officer of Dr. Barnardo's Home in London (Figs. 52 and 53).

The hands and feet in these illustrations are from the same subject. The hands appear to be wanting in fingers, but the skiagram shows that it is really a case of polydactylism, with supernumerary thumb. One of the missing fingers, the digit of the right hand, appears to be represented by a rudimentary phalanx forced down between the heads of the second and third metacarpal bones.

The feet, however, show suppression of toes, and suggest a two-toed type. The picture of the right foot is indistinct, owing to trembling of that limb during the exposure. It is interesting to note that the other foot and the hands were not affected in a similar way, but were perfectly steady—a fact which may possibly point to some nerve instability or other local peculiarity.

Dress deformities may be demonstrated in a striking way by the Röntgen rays, which should place a new weapon in the hands of the advocates of rational dress. Thus, the distortion of the ribs due to the wearing of tight stays lends itself to this kind of illustration. Some time since a series of such skiagrams was shown to the Académie de Médecine by Madame Gaches-Sarrante, a Paris physician. Boot deformities are also readily demonstrated, whether of dislocated phalanges, bunions, or damage to the tarsal arch.

The various deformities due to hypertrophy and other changes in the structure of bone, as in rickets, gout, syphilis, Charcot's disease, have been already spoken of. They are all open to Röntgen ray exploration. The deformity of a hand due to rheumatoid arthritis has been already discussed.

VI. MAPPING OF SKIN SURFACES.

*In the course of certain experiments with the Röntgen rays the writer found that it was possible to obtain a record of the coarser fissures of the skin surface. The primary object of investigation was to note the results of skiagraphing *in situ* the commoner pigments and drugs applied to the skin. It was found that oxide of bismuth, powdered freely over the back of a finger, gave a good

* From the *Brit. Med. Journal*, March 27, 1897.

tracing of the creases over the knuckles. Following up this clue a fairly perfect record was obtained of the skin surface, as shown in the frontispiece of this book. The best results were secured by kneading putty into the skin, then working up the surface with glycerine, and finally gently and smoothly rubbing with subnitrate of bismuth.

As to the practical value of such a skin skiagraph there is little to be said at present. That a record can be obtained in this way of every local peculiarity seems to be undoubtedly proved by the plate; over the phalanx of the thumb a small convoluted cicatrix of the surface markings could be clearly seen in the original by means of a lens. Such a permanent record might be of value in the identification of criminals, after the fashion invented by M. Bertillon, of Paris. It seems more than likely, however, that a similar end may be obtained by far simpler means. A reference to the figure will show that the addition of the surface markings gives a striking perspective effect that is wanting to the ordinary skiagram. The lines are evidently due to the heaping up in the furrows of a substance opaque to the rays.

The surgeon does not always find it easy to cut down upon a needle, or other small object, even when it has been precisely localised by a Röntgen ray examination. In those parts of the body where well-marked skin furrows are found, it would be easy enough to reproduce them in the manner indicated. In that way a complete surface map, with lines of longitude and latitude, would be available as a guide to the knife of the operator.

The original skiagram was taken by Mr. W. Cox, watchmaker, of Parkstone, Dorset, with a powerful coil constructed by himself.

VII. OTHER SURGICAL POINTS.

To ascertain Results of Osteoplastic Operation.

An interesting case is recorded by Howard Lillienthal in which both the desirability and the results of a bone plastic operation were plainly indicated by the rays. His patient had lost the use of a leg after a severe injury. A skiagraph showed considerable loss of substance of the body of the tibia. To remedy this state of things the operation of tibio-fibular osteo-

Fig. 52.—Polydactylism: Hands of a Girl of Twelve.
(Taken by Mr. Greenhill.)

Fig. 53.—Feet of same Patient, showing Suppression of Toes and probable Reversion to Two-toed Type.

plasty was performed by cutting through the fibula, and bending it over to lie obliquely in the long axis of the gap in the shin bone. The successful result was proved some time afterwards by a Röntgen ray photograph, which revealed bony filling of the gap and restoration of the line of the fibula, with union of the two bones by an osseous bridge.

Separation of epiphyses in young subjects can be readily detected by the rays. In some cases it is of importance to recognise this injury. For instance, in an injury to the shoulder there is much less likelihood of impairment of movement by callus in separation of the upper epiphysis of the humerus than in extracapsular fracture of the surgical neck.

Ossifications of various kinds can be detected. Examples are those occasionally met with in muscle, as the adductors of a rider or the deltoids of a soldier, known respectively as 'rider's bone' and the 'drill-bone.' Another instance is the ossified insertion of rectus femoris muscle in Charcot's disease.

Ossifications of the costal cartilages are shown in old persons. One remarkable instance of premature ossification of the kind in a young woman of twenty has been reported as disclosed by the rays.

Calcification of arteries can be shown in the limbs. Possibly, as methods improve, atheromatous changes may be shown in the heart and larger deep blood-vessels.

The sub-periosteal enlargements met with after injury in strumous subjects are well shown by the Röntgen rays. In one such case of 'strumous dactylitis' a boy of fourteen suffered from a swollen finger after a fall some weeks previously. A photograph taken by the writer revealed a considerable periosteal enlargement of the first phalanx of the third finger. The effused material, however, was not opaque as a whole, but showed a few granules, apparently of commencing calcification or ossification. The lower epiphysis appeared to be partly obliterated, probably owing to the tilting up of the inter-epiphyseal cartilage by the swelling of the finger, whereby the direct passage of the rays was prevented.

Action of the Rays upon Micro-Organisms.

The Röntgen rays do not appear to exercise any injurious effect upon micro-organisms. Numerous experiments have been made. Thus, Professor W. W. Keen, of Philadelphia, reports* of pink streptococcus, anthrax, *Micrococcus prodigiosus*, *Micrococcus cereus flavus*, *Sarcina aurantiaca*, yellow sarcina, tubercle bacilli, that after exposures first of half an hour, and then twice for fifteen minutes, neither lethal nor inhibitory effects were exerted upon the cultures. These experiments confirmed conclusions previously published by Dr. Davis in the same journal.

Berton† exposed bouillon cultures of the diphtheria bacillus to the rays for periods of sixteen, thirty-two, and sixty-four hours, but in no instance did he note any injury to the vitality of the organisms.

J. Brunton Blakie, M.B.,‡ as the result of numerous experiments carried out at the University of Edinburgh, concluded that the Röntgen rays have no visible influence on the growth of cultures of the tubercle bacillus, and that the delicate chemical structure of diphtheria toxine, like the delicate chemical structure of the retina, is not affected by their vibrations.

* *The Amer. Journ. of Med. Sciences*, March, 1896.
† *Bull. Gén. de Thérap.*, November 8, 1896.
‡ *The Scottish Medical and Surgical Journal*, May, 1897.

B. DENTAL SURGERY.

Now and then some practical help may undoubtedly be derived from the Röntgen rays in dental surgery. The teeth offer greater resistance than bone, and hence throw a distinct shadow when embedded in osseous substance. A good idea of the skiagram produced by teeth can be gathered from the teeth shown in Fig. 54, taken from the private collection of Mr. Louis Maitland. They illustrate various pathological conditions, and may be briefly described, taken in series from left to right, and in lines from above downwards.

1. Upper molar, showing exceptional size of fangs and lateral carious cavity.
2. Upper molar, with carious cavity, nerve canals well shown.
3. Molar with carious cavity.
4. Molar with exostosis of fangs.
5. Upper central incisor: exceptional development of fang. Firmly united to its inner surface is a supernumerary tooth, faintly outlined in skiagram.
6. Bicuspid: cavity of decay communicating with nerve canal.
7. Upper central incisor: showing sphere of erosion, which is indicated by a faint shadow at the neck of the crown. This curious pathological condition, the cause of which is not exactly known, is in its usual site, partly above and partly beneath gum.
8. Upper bicuspid: eccentric distortion of fang. This shape is the result of pressure of neighbouring teeth in process of development. Absorption going on in centre cf single fang is indicated by the darker area; that is, the thin plate of tooth substance has offered little resistance to the rays.
9. Upper central incisor: half the fang absorbed; small carious cavity. This tooth is extremely opaque, shown by its

relatively white look and absence of dental canal tracing, a condition probably due to its necrosis.

10. Lower molar, with large amalgam stopping reaching nearly to apex of fang; that is to say, the filling is nearly all beneath the level of the gum. The metal shown by a dense white patch. Compare this absolute density to the Röntgen rays with that of the preceding tooth.

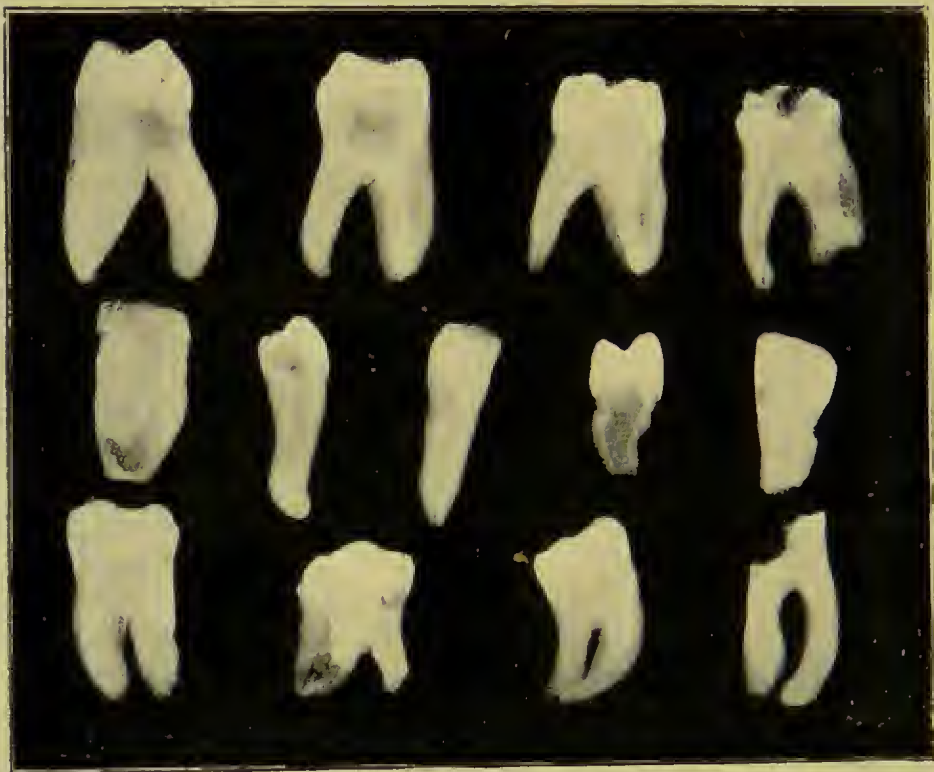


Fig. 54.—Skiagram of Teeth, showing various Pathological Conditions.

11. Permanent upper molar: fangs absorbed by pressure of wisdom tooth, which was impacted between them.

12. Wisdom tooth: fangs sharply hooked.

13. Lower molar, showing convergent fangs and carious crown, rendering extraction difficult.

Mr. Frank Harrison published some of the earlier skiagrams of teeth *in situ*. In the *Journal of the British Dental Association* for September, 1896, he has an excellent photograph of a portion of the lower maxilla of a girl of seven. The milk-teeth with

their pulp-cavities and fangs are clearly visible, while below the roots of the first and second temporary molars are the permanent first and second bicuspids enclosed in their respective bony crypts. The skiagram displays the internal structures of the lower jaw well-nigh as distinctly as would be done by a dissected specimen.

Mr. Harrison observes: 'The x-rays promise to be of great use in dentistry, and will enable the dentist to observe in living tissues what was possible only a short time ago in the dead subject. The genesis of the teeth, the construction of artificial crowns, the anomalies of roots, the difficult eruption of teeth, and many other conditions of organs which are enveloped in tissue opaque under ordinary conditions, become visible by the illuminations of the x-rays.'

In one important particular the rays are likely to be of great service to the dental surgeon, namely, in the deformities of the jaws due to or connected with non-erupted teeth. In such cases he may be able to ascertain with exactitude the position, shape, and size of the teeth within the bone. From the information thus gained he will be able both to plan and to perform his surgical operations with exactitude, whereas under previous methods the most skilful man had to act upon probabilities. Lastly, a pathological condition in which the new method will be now and then valuable is the tooth-bearing cavity in the substance of the jaw, known as the 'dentigerous cyst.'

C. MEDICINE.

VIII. CHEST AND ABDOMEN.

Hitherto the most striking practical applications of the rays have been made in surgery. There can be no doubt, however, that the future has in store a brilliant field for Röntgen photography with regard to clinical medicine. In the thorax a great deal has been already achieved by demonstrating changes in outline of the heart and aorta, as well as in the substance of the lungs, mediastina, and pleura. As to the abdomen proper, results have so far not been very encouraging—at any rate, in the adult. It may be confidently hoped, however, that before very long we shall be able to explore all internal regions accurately by means of apparatus of sufficient penetration. Indeed, there are indications that the presence of tissues that offer little resistance to the Röntgen rays will be sooner or later detected.

Good results as to internal organs can be obtained in the case both of small lower animals and of children. This is well shown in the illustration of the half-grown cat (Fig. 55). The picture in question shows clearly the windpipe and its division into bronchi, which again bifurcate in the substance of the lung. The heart is outlined in front of the chest, and, so far as one can judge, the bones of the sternum are shown through the less opaque cardiac substance. The delicate shoulder-blade is well recorded, and the lower margin of the thoracic cavity is sharply defined by the edge of the midriff. In the head, the fangs of some of the teeth can be seen in their bony sockets, especially in the molars of the lower jaw. The cartilages of the nose and the ears are faintly shadowed, and various muscular and tendinous structures can be made out in the neck.

The abdomen of this cat was by no means so clearly mapped out by the rays, but, nevertheless, contained several valuable

FIG. 55.—HALF-GROWN CAT, SHOWING BRONCHI, LIVER, HEART, ETC.
(Reduced one-half. By Mr. Cox, Parkstone.)

indications. The main mass of the liver, for instance, was sharply outlined in its upper, but diffuse in its lower, margin. The stomach probably corresponded with a light space beneath the liver. The broad light band that curved from the centre of the diaphragm to the lower part of the lumbar spine appears to represent large intestine. Other convolutions of intestine were clearly shown, especially in the case of a coil of gut that had an extremely light record near the pelvis. This bend of intestine had, most likely, been full of gas, and had lain close to the surface of the sensitive plate during exposure.

The tendons, passing from the leg to the os calcis behind, and to the instep in front, were plainly pictured in the original print.

This skiagram has been dwelt upon at some length because it gives a good idea of what may be hoped for in the future. It was taken with a powerful coil, giving a spark of over a foot in length. There seems to be little reason to doubt that what is possible with lower animals will before long be attainable in the case of living adult human beings, so that all deep-seated organs will be brought within the reach of this new method of exact investigation. In other words, the Röntgen rays will some day render to medicine services not less conspicuous than those already conferred upon surgery.

Dr. Macintyre,* who was the pioneer in this country of internal skiagraphy, has laid down the following rules: (1) A powerful current, 30 to 33 ampères, is necessary, so as to take the photograph instantaneously. (2) The transformer needs a large coil, which will give a 6, 8, or 10 inch spark. (3) It is best to use a small focus tube, which may require prolonged heating. (4) Rapid exposure is absolutely necessary. (5) A mercury interrupter is useful, instead of a spring. He usually places a lamp about 3 feet from the sensitive plate. This distance gives a well-defined shadow, but requires a strong light.

In the *Lancet* of October 10, 1896, Dr. Campbell Thomson, Medical Registrar of the Middlesex Hospital, says that the fluorescent screen is quicker and better for clinical purposes. By that means it is possible to clear up many difficulties, such as exist in aneurism both of the heart and of the first part of the aorta. He has given several valuable practical hints upon chest skiagraphy. To get a fixed location-point, he suggests a metallic

* *Lancet,* August 22, 1896.

button placed over the nipple, to which it may be secured by a piece of sticking-plaster. In order to secure a record of what is seen in the fluoroscope, he fastens to the back of the fluorescent screen a sheet of white paper, through which the rays would of course pass. He then slides a flat metallic pen or pencil between the chest and the paper, and on the latter he traces the outline as projected in the fluoroscope. It need hardly be added that to carry out this manœuvre the observer would have to continue looking at the screen, so as to ascertain and control the movements of the opaque pencil.

The shadow of the heart is lighter at the pulsating margin. Between it and the liver, upon taking a deep breath, a light interval appears. From the front of the chest the whole of the cardiac outline can be seen; but from the back much less can be seen, as the view is obstructed by the spine. From the back a definite shadow with well-marked external border can be seen on the left, and a smaller and less intense shadow, corresponding to the right auricle, can be seen on the right of the spine.

The shadows, whether seen from the front or the back, can be conveniently recorded on one of Danielssen's clinical diagrams of the chest.

If a photograph be taken of the whole heart, it is best taken with the sternum next the plate.

The original of the accompanying skiagram of the thorax was taken by Mr. Greenhill from a boy of fourteen, lying on his back. The exposure was twenty minutes, distance of tube from plate 30 inches, spark 6 inches, Apps' coil (Fig. 56).

It should be borne in mind that fluoroscopy is an art that requires patient study. The education of the eye to recognise objects of varying opacity on the screen can be obtained simply and solely as a matter of practice. A similar observation is to a less extent true of the reading of skiagrams.

The Lungs, Heart, and Great Vessels.

Dr. Disan* has introduced an ingenious method of recognising alterations in the cardiac outline. First of all he marked on the chest what should be the normal shape of the heart, and mapped out the area thus obtained with a copper wire, which he

* *Dominion Medical Monthly*, February, 1897.

PLATE 56.

fastened to the chest with ordinary plaster. He then examined with the fluoroscope in the following way:

'At first the greatest strength of current obtainable from the apparatus is turned on. The observer then looks through the fluoroscope, and gets the chief landmarks of the chest—such as the scapula, ribs, spine and convexity of liver—the wire being at the same time in view. The current is then reduced until the heart becomes visible. The fluoroscope is applied to a spot marked at the left of the spine corresponding to the fourth intercostal space in front of the chest.'

In a case, under Dr. Coupland, of doubtful deep aneurism of the chest, the diagnosis was cleared up by the fluoroscope. From the front, slight hypertrophy was noted, and just above the junction of the left cardiac border with the sternum a faint indefinite shadow. From the back, a well-defined shadow was seen on both sides of the spinal column, at about the level of the fourth dorsal vertebra. On the right border this outline was convex and pulsating; the intensity of the shadow on that side was almost the same as that of the heart, while on the left it was lighter and less definite. The evidence thus obtained converted a doubtful into a certain diagnosis.

The pulsating margin of a non-cardiac shadow in the thorax of course points to aneurism.

The fact that the lungs are full of air and easily permeable to the rays makes it possible to get a good outline of the human heart. As the result of a number of experiments on the dead body, Pöch demonstrated to the Vienna Gesellschaft in January, 1897, that it was possible in the empty heart to make out the valves and trabeculæ as clear spaces against a darker cardiac background. When the heart, however, was full of water or of blood, no such differentiation could be made.

This relative opacity of blood is an important quality so far as concerns the Röntgen diagnosis of alterations in the form of the heart and bloodvessels. The reason why a bloodvessel should resist a long exposure is obscure. We know that after prolonged exposure both biliary and uric acid calculi will cease to cast any shadow, while a rib nearly ceases to do so, and a phosphatic shadow becomes much lighter (Dr. Swain's experiment, p. 62). Mr. C. W. Mansell-Moullin mentioned to the writer a case in which the abdomen was exposed for two hours. The bones left

no record, but the abdominal aorta threw a strong shadow. This interesting observation might possibly be explained by the projection across the field of an opaque fluid moving in a current, the swiftness of which prevented any one portion of the column being exposed long enough for penetration by the rays.

On December 7, 1896, Professor Bouchard read a paper before the French Académie des Sciences on 'Pleurisy in Man studied by the Help of the Röntgen Rays.' He pointed out that the thorax, viewed from behind by a phosphorescent screen, when traversed by the rays, showed to the right of the spine and towards the middle of the dorsal region a pulsating shadow of the heart. At the same time the liver could by means of its shadow be seen rising and falling in the chest cavity as it followed the respiratory movements. Apart from the shadows of bones, heart, and liver, the rest of the interior of the thorax was transparent.

In a right-sided pleurisy with effusion, Bouchard found a darker shade on the affected side of the chest as compared with that of the sound. Further, the shadow indicated the upper limit of the effusion, as proved by percussion and by other ordinary methods of physical diagnosis. The tint, moreover, grew deeper from the upper border, where the layer of effusion was thin, to the lower part, where the shadow merged into that of the liver.

In three cases he also noted to the left of the vertebral column a triangular shadow, the base of which was continuous with the heart. This he explained as the mediastinum pushed over sideways to the left by the effusion. In a fourth case, retraction of the affected side had drawn over the mediastinum to the right.

In a further communication to the Academy (December 14), the Professor remarked that, in most of the cases of pleurisy with effusion previously described, he had noted with the fluoroscope that the lighter area increased from above downwards as the effusion lessened. In one case, however, the apex of the chest retained its shadow. This fact suggested consolidation of the lung at that spot, a suspicion that was confirmed by percussion and auscultation. In other instances tubercular deposits were localized by the same method.

'In all tuberculous subjects,' writes Dr. Bouchard, 'examined

by the phosphorescent screen, I have established pulmonary lesions by a shadow, the area of which corresponded with that mapped out by other methods of physical examination, and the intensity of which was in relation to the gravity of the lesion. In two instances the appearance of clear spaces pointed to cavities, a diagnosis verified by auscultation. But in a third case, where auscultation led one to suspect the existence of cavities, nothing of the kind was visible on the screen. In another patient the general symptoms pointed to early phthisis, but no tubercle bacilli were found in the sputa, and the physical signs were indecisive. The skiascope showed that the apex of one of the lungs was less permeable to the rays, and in a few days both auscultation and bacteriological examination of the sputum yielded positive results.

Some no less important reports were published by the same observer in the succeeding issue of the *Comptes Rendus* (December 28). In one case the whole left lung was obscured. This appearance was attributed either to pleurisy with effusion, or to general tuberculosis of the left lung. On further examination it was noted that the mediastinum was not pushed to the right. By a process of exclusion, therefore, the diagnosis of tubercle of the whole left lung was arrived at. In another case, on the left of the spinal column in a little girl, was demonstrated a tumour, due to adenoma of bronchial glands. In a third patient, a dark shadow on the right side of the chest, continuous with that of the sternum, was shown to be due to a transposed heart. Owing to the heart's impulse being on the right side, the presence of aneurism had been suspected. Other conditions recognised include aneurism of the arch of the aorta, with a clear view of its position, outline, and size; pulsation of the aorta to the right and left of the sternum; compensatory hypertrophy of the heart in arterio-sclerosis; and beating of the auricles to the right of the sternum, in such cases due to kidney disease.

Bergoiné has repeated and confirmed the above observations.*

At the Medical Club in Vienna, in January, 1897, Professor Wasserman showed two cases that he had diagnosed by the Röntgen rays. The first was a case of phthisis in the right lung, where the cavernous signs could not be elicited by percussion and auscultation. Under the rays the left side of the chest

* *Gazette des Hôpitaux*, January 7, 1897.

appeared clear and healthy, while the right exhibited diffuse shadows representing infiltration; in one place a clear area, which to all appearance corresponded to a cavity, was brought out by the light when applied either in front or behind the right lung. The second case was that of an aneurism in the left mediastinum, where the fluoroscope demonstrated a dark space, the margin of which moved with a distinct impulse, and thus established the differential diagnosis between solid tumour and aneurism.

Lévy Dorn examined with the screen the chest of a patient suffering from chronic bronchitis and asthma. He observed that the left half of the diaphragm fell rapidly at each inspiration, while it rose by slow successive stages. The right half, on the other hand, remained from the first absolutely fixed in the position of extreme inspiration, only to rise at the termination of the attack with the expectoration of viscid mucus.

In commenting upon the foregoing results, Mr. Sydney Rowland* makes the sound remark that while they suggest that the screen is a valuable addition to our means of physical examination, they cannot replace other existing methods as regards either rapidity or ease of application.

Mr. Bezley Thorne† has made an important observation in relation to cardiac skiagraphy. He noticed that the heart shrank visibly after thirty minutes' exposure to the Röntgen rays. In one case the lessening amounted to no less than 2 inches in the long axis of the viscus, and 1½ inches in the short diameter. There may, of course, be some fallacy involved in this interesting phenomenon. For instance, it is known that increased exposure to the rays in many cases means greater penetrability of any given substance. So that the appearance of a light zone round the heart towards the end of a long exposure might mean that so much of the muscle had become fully penetrated. In that case the dark core would probably represent blood.

Should, however, actual contraction be proved, it points to possibilities of importance. Without venturing too far afield in abstract speculations, it seems tolerably clear that, assuming such contraction, there might be: (1) traumatic injury to deep organs from the skiagraphic exposures; (2) direct tonic influence on heart muscle.

* *Brit. Med. Journal*, June 12, 1897.
† *Brit. Med. Journal*, vol. ii., p. 1238, 1896.

An interesting study in therapeutics has been made by Professor Grunmach.* By means of the fluoroscope he traced the action of digitalis upon the heart in aortic and mitral insufficiencies, and other conditions resulting in cardiac dilatation and hypertrophy. He also made the practical suggestion that the action upon the heart of various medicinal and toxic drugs might be studied by means of the Röntgen rays.

The Abdomen.

The application of the Röntgen rays to the abdomen has not hitherto yielded results at all to be compared with those derived from the thorax. The upper border of the liver, as already stated, can be well seen, and a hydatid tumour has been reported projecting from its convex surface ; but the lower border is rarely to be made out. The kidneys are not visible. The stomach is sometimes faintly outlined, presumably most so when filled with gas. The intestines are to be seen at times faintly outlined. In an experiment conducted by the present writer, a skiagraph was taken from a stoutly-built young officer thirty years of age. He had been affected for many years with signs somewhat suggestive of intestinal obstruction following peritonitis. For a fortnight before being skiagraphed he took 15 grains of bismuth three times a day. The result shows a faint outline of stomach and colon, with some coils of small intestine and sigmoid flexure. It seems fair to assume that this result may—in part, at any rate—be attributed to the opaque bismuth present in the intestine. The skiagraph was taken with an Apps coil, 9-inch spark, and an exposure of 15 minutes, the patient lying on his belly.

In the case of cancerous masses of the stomach, Bouchard failed to obtain any positive result even with a coil that gave a spark of 15 inches.

Murphy's buttons, coins, and other foreign bodies have been detected in the abdomen, more especially in the case of children. It is obvious that such localization might afford simply invaluable aid to the surgeon.

Calculus of gall-bladder, kidney, and urinary bladder have all been detected *in situ* in the living adult. They are described

* *Therapeutische Monatshefte*, January, 1897 : 'Ueber die Bedeutung der Röntgen-strahlen für die innere Medicin.'

more fully in the section upon foreign bodies (p. 68). Results in each case, however, are still more or less uncertain. Much the same statement applies to the skiagraphic examination of the uterus, with its contents and appendages, a subject dealt with under the heading of obstetrics (p. 120).

Practical Conclusions.

To sum up the applications of Röntgen rays to clinical medicine: First of all, we find that satisfactory results are confined chiefly to the thorax, although now and then useful information has been obtained from the abdomen. Secondly, in the lungs we can sometimes get early information as to tubercle, which may not be disclosed by ordinary means of physical or bacteriological examination, that effusion of fluid in pleura may be accurately estimated, and presumably that also of pericarditis and of various non-inflammatory local dropsies. As to the heart and large vessels, enlargements and displacements can be readily demonstrated, together with thoracic aneurism. Such alterations can be detected when cloaked from ordinary examination by emphysema of the lung. The results of the Schott plan of treatment of heart disease can also be ascertained.

One important point is the localizing possibility of patches of tubercular consolidations and cavities in the lung substance. Hitherto one of the chief obstacles to the progress of lung surgery has been the difficulty of exact localization. Thus, it not infrequently happens that the physical signs point to the presence of a cavity where that particular lesion, in point of fact, does not exist. If this diagnosis, then, could be cleared up definitely by a skiagram or by the phosphorescent screen, the hands of the surgeon would be considerably strengthened in dealing with individual cases. As blood is opaque it may be possible to skiagraph apoplectic clots in the brain.

Calcification of Arteries.

As might be expected, a skiagraphic record can be usually secured of calcification in arteries, whether primary of the middle coats or secondary of the inner.

IX. ACTION OF THE FOCUS TUBE UPON THE SKIN AND DEEPER STRUCTURES.

Among the many interesting results of the application of the Röntgen rays to the human body, not the least remarkable is their effect upon the skin. Broadly put, in some cases and under certain conditions they set up a dermatitis. The parts thus affected are the skin, conjunctiva, hair, and nails, and the damage may be either so trifling as almost to escape notice, or of a severe nature. In one case the present writer took two skiagrams of a lady's hand with an exposure of four minutes, and the tube at a distance of 12 inches. Some days afterwards the patient volunteered the information that she had felt something wrong with one of her fingers ever since the taking of the Röntgen photograph. On examination, the nail of the ring-digit was found in a state of partial dusky erythema. This slight traumatism would almost certainly have been overlooked had not the patient herself drawn attention to the fact.

A large number of instances of severe damage have been recorded.

Thus, in the *British Medical Journal* epitome for August 15, 1896, the case of a young man of seventeen was reported. He was under the care of Marcuse, who found the patient suffering from a diffuse desquamative dermatitis of the face and back. There was also a partially-bald patch on the temple, from which the hairs could be easily extracted.

In the same journal for November 17, 1896, Dr. Drury described a case in which severe results followed two exposures, the first of an hour, the second of an hour and a half. A large surface of the epigastrium became erythematous and swollen; it vesicated on the tenth day, and showed a profuse discharge on the twenty-fourth day. A troublesome ulcer which ensued was unhealed sixteen weeks later.

In the *Canadian Practitioner* for November, 1896, Dr. King, of Toronto, reported the case of a young man who for three months was engaged in demonstrating the Röntgen rays, with a daily average exposure of six hours. After about six weeks he had dermatitis of the right arm and hand, which recovered after discontinuing the exposure. On resuming work, however, he had a

second attack. In about six weeks the hand and face of the exposed side showed signs of a severe dermatitis. The eyelids were œdematous, and there was double conjunctivitis. On the left hand the nails exfoliated and the hairs were destroyed. Mr. George Pernet has published an abstract of the case in the *Dermatological Journal* for January, 1897. On the left side the hair was gone from temple, eyebrow, upper lip, side of face, and neck.

In the *British Medical Journal* for January 2, 1897, Dr. Radcliffe Crocker recorded an interesting case where a lad developed a severe dermatitis of the abdomen after a single exposure of an hour's duration. Six weeks later there was still a small painful ulcer left unhealed.

In the *Scottish Medical and Surgical Journal* for February, 1897, Professor Waymouth Reid, of Dundee, published an account of his own experiences. He underwent four exposures: on the first day, one of twenty and another of forty minutes; next day, one of fifty minutes; and on the fourth day, one of ninety minutes. His belly and chest were severely affected, and his back less so. The skin lesions were healed by the thirty-third day. Sixty-nine days after the original exposure, Professor Reid reported: 'There is no vestige of hair left upon the chest, and I have not been troubled with the shaving of my chin for the last six weeks, the hairs having come out by the bulbs to the touch of the razor twenty-two days after the chest exposure, after a slight preliminary erythema of the skin, not followed by loss of cuticle.' He has since informed the writer that the hair has grown again.

Many other similar cases have been recorded. When the rays are directed upon the scalp in susceptible persons, they appear to cause shedding of hair without severe reaction. The nutrition of the hair-bulb is interfered with, possibly by some vascular changes leading to exudation and intrafollicular pressure. At the Vienna Gesellschaft, in January of this year, Zemann stated that he found many different changes in hairs that had been treated by the Röntgen rays. The hair-root was always thinner, and the shaft brittle; the hair itself might be of the usual thickness, or often cone- or spindle-shaped, with fibrous swellings. At the same meeting, Kaposi remarked that the hairs shown by Zemann were like those met with in the microscopic examination of alopecia areata, and he thought them due to a similar pathological change. This last point is interesting as tending to throw

some sort of side-light on alopecia areata. It would seem that by bringing a focus tube near the scalp, and exposing the latter to a somewhat prolonged action of the rays, we can produce an artificial *area*. Not only that, but we have the high authority of Kaposi that the pathological hairs resulting from the ray exposure cannot be distinguished from the diseased hairs of alopecia areata. Twenty-seven cases of supposed *x*-ray injury have been published by Mr. T. C. Gilchrist.* Among them is that of Professor E. Thomson, who was sceptical of the traumatic action of the rays. He accordingly exposed his hand for half an hour at a distance of a few inches from the tube. An eruption followed nine days afterwards. Another remarkable case quoted is one reported by Dr. F. Kolle, of a boy whose whole body was exposed to the rays for forty minutes, and who sixteen days later lost his hair. In Gilchrist's own case, a demonstrator of the rays, thirty-two years of age, after frequent and prolonged exposures developed a severe dermatitis. The bones of the hand became very painful on pressure. The skiagraph showed distinct osteoplastic periostitis, and probably an osteitis of first and second phalanges of the index and second fingers, and also of the heads of the metacarpal bones.

Gilchrist mentions three theories:

1. Professor Thomson thinks the traumatism due to the *x*-rays, or something that goes with them. He was led to that belief because, in his own case, he used a Crookes tube of blue glass with a clear window, and found the skin affected only opposite the clear space.

2. Tesla supposes it to be due to the action of ozone generated in the skin.

3. Gilchrist himself thinks the injury may be due to minute particles of platinum from the kathode rays.

It is clear that, if the observation as to traumatism of deep structures be true, then Tesla's ozone theory does not afford the key to the matter, for that applies only to the surface.

Although most observers agree that the dermatitis occurs independently of the length and frequency of the exposures, the point is still doubtful.

A point that has struck most investigators is the similarity of the lesion to severe sunburn. Gilchrist admits the likeness,

* *Johns Hopkins Hospitál Bulletin* (No. 71, February, 1897).

but says the two things are different, because in solar eruptions there is no alopecia and no periostitis. The objection, however, does not appear sound, because there is obviously traumatism to deep structures in sunstroke. Again, one would be inclined to connect the thickness of the negro skull with the effect of the sun.

In one striking case reported to the writer a patient suffered from cerebral symptoms exactly similar to sunstroke. He was in the habit of demonstrating the Röntgen rays, and often had one side of his head close to a focus tube, separated only by a wooden screen. From time to time he suffered from slight dermatitis. At length he developed a more serious illness. His chief symptoms were vertigo, headache, vomiting, dimness of sight, and entire prostration. He was under the care of a medical man, who said, at the time, his symptoms were practically those of sunstroke. If this be the case, and if we can ascribe this cerebral attack to the influence of the rays upon the brain, then we must admit a further analogy between sun and focus-tube traumatism,* namely, the power both possess of affecting deeper structures. In this patient the giddiness persisted for a couple of months.

Another case has come under the notice of the writer. A practical worker with the rays, a healthy, middle-aged man, was carrying out a series of experiments involving exposure of the region of the stomach for a period of about two hours daily. After some weeks he complained of abdominal symptoms, such as pain, tenderness, flatulency, and diarrhœa. He went away into the country for a fortnight and got well. On his return he resumed his experiments, and after a fortnight experienced a second similar attack. He then shielded his stomach with a thin sheet of lead, and his symptoms finally disappeared. This history certainly suggests that in his case the rays of the focus tube caused a direct inflammation of the gastro-intestinal mucous membrane.

Other facts pointing to deep action of the focus-tube rays are the local tremors often set up by exposure, and the apparent shrinking of the heart beneath the rays, noticed in several instances by Mr. Bezley Thorne.† Lastly, there is the action, noted by Despeigne‡ and others, of these rays in the relief of pain.

* 'Focus-tube traumatism' is used, as we cannot identify the injurious rays.
† *Brit. Med. Journal*, vol. ii., p. 1238, 1896.
‡ *Lyon Med. Journal*, December 28, 1896.

In his smaller Clinical Atlas, Mr. Jonathan Hutchinson gives an excellent picture of a severe dermatitis following a single exposure to the sun. Numerous instances are on record of focus-tube dermatitis following a single exposure. In both cases the injury takes a week or more to develop fully, a fact that is certainly suggestive of a secondary inflammatory reaction, connected with the sloughing of necrosed tissue. In both instances, too, the injury is in the great majority of cases superficial; thus, in Professor Reid's case, the rays passing through his body damaged the skin at the point of entry and exit.

Another remarkable point is pigmentation. Bronzing is a constant result of exposure to the sun; most people would connect the black skin of the negro with the action of the sun upon his ancestors. In one case,* that in which Despeigne used the rays to treat the pain of cancer, after the eightieth sitting the skin of the side of the neck exposed became almost as black as that of a negro. In this connection may be mentioned the bronzing sometimes seen in those exposed to electric light.

Lastly, we have the important influence of idiosyncrasy. Many people are exposed both to hot sun and to Röntgen-ray demonstrations, but comparatively few suffer in consequence. Predisposition of some kind appears to be an absolutely essential factor. The peculiarity may lie in the skin, but it seems more likely to be in the blood, especially as the latter is attracted to the skin in greatly increased volume in response to many external irritant influences. It may be that the focus-tube rays, like the sun and other external irritants, stimulate the excretory function of the skin into unusual activity, and that the outward passage of some irritant from the blood sets up the dermatitis.

Personally, the writer is inclined to think that the focus-tube traumatism may ultimately prove to be due to heat rays—in other words, to be a kind of burn. The kathodal rays strike the platinum anode or anti-kathode and make it hot; they are reflected to the wall of the Crookes tube, where they are in part converted into Röntgen or x-rays. What becomes of the rest of the kathodal rays is not quite known, but it is generally believed that some of them, at any rate, are converted into heat rays, by which means a tube in action becomes warm.

This heat-burn theory was suggested to the writer by the

* *Lyon Med. Journal*, December 28, 1896.

two following cases, brought under his notice by Mr. Webster, of Blackheath, a gentleman who has had considerable experience of Röntgen-ray work. In the first instance, he exposed an individual something like a score of times during a period of six months. Six weeks after the last exposure the hair fell out from one side of the head. The only differing condition of experiment, so far as could be ascertained, in the last or damaging exposure was that the kathode at the end of the Crookes tube had been kept continually heated.

The second case was that of Mr. Webster himself. For a year or more he had undergone constant exposure to the rays without bad results. He then injured himself with a metol developing solution, and shortly afterwards a diffuse dermatitis appeared on the back of his hand. This traumatism, again, coincided with the heating of the kathode end of the tube.

Now, in both the foregoing instances previously unsusceptible persons became susceptible under altered conditions of experiment. The alteration consisted in heating the kathode end of the tube, which means, when applied to a Crookes tube in action, an increased production of kathodal rays. These kathodal rays, as already stated, are in part converted into heat rays upon striking the wall of the tube. There thus appears to be some probability that in heating the kathode end of the tube we increase the resulting heat rays thrown off from the tube. Lastly, the kathodal rays strike the platinum anode, or anti-kathode, and render it red-hot, and it is not unreasonable to suppose that their contact with the skin surface might similarly have a calorific effect.

On the whole, it seems not improbable that some common agent exists in the rays of the sun, of the focus tube, and of the electric light, capable of stimulating the human cutaneous surface, and sometimes the deeper tissues of the body, in varying degrees of severity, which are in some way determined by personal predisposing peculiarities.

X. THERAPEUTICS.

The possible curative action of the Röntgen rays has given rise to many proposals. There can be no doubt that under some imperfectly understood conditions they are able to exert considerable influence on the cutaneous surfaces of the human body.

Whether this be due to the unmixed Röntgen rays, or to a ray of some other kind, need not be further considered here. It seems clear that rays of various qualities are combined in their exit from the Crookes tube, but they must be treated as a whole in considering their effect upon living tissues. So far, it has been generally assumed that the effects, varying in degree from simple congestion to severe destruction of tissue, have been confined to cutaneous surfaces.

Recently, however, some observations have come to light which point to an action of the Röntgen rays upon the deeper parts of the body.

Superficial Action of the Röntgen Rays.

The action of the rays upon the skin appears to be that of an irritant towards predisposed subjects. So far as can be judged at present, its only likely therapeutic value to dermatologists will be as a depilatory. Freund* has applied the method with some success to an extensive nævus pigmentosus pilaris in a child. Whether the depilation thus obtained can be rendered permanent remains to be discovered. Certainly, in the cases hitherto reported the hair has sooner or later reappeared. Again, there is no certainty in the resulting depilation. Dr. Low has informed the writer that he tried on various occasions to depilate a hairy mole in a child sent to him for treatment, but without success.

It is evident, then, that we have in the focus rays an agent capable of acting powerfully upon the skin and its appendages. At the same time, the action is so uncertain, so difficult to regulate, and so apt to be attended with serious complications, that it is not likely to have any but an extremely limited application to the therapeutics of the cutaneous surface.

Turning next to the possible therapeutics of the Röntgen rays upon the deeper structures, we find ourselves confronted with several interesting and suggestive facts.

In some instances exposure to the rays has been followed by a cessation of pain, but the casual relationship between the two conditions can hardly be regarded yet as scientifically demonstrated. Probably the first notice of the kind was by Dr.

* *Medical Press and Circular*, January 27, 1897.

Richardson* of Boston, who wrote to a medical journal on August 31, 1896, describing the results of an examination by the rays. The patient was a stout woman of fifty, who had been complaining of pain on and off in an old fracture near the ankle-joint. She had an exposure of five minutes, and three weeks later wrote stating that, in the interval, not only had she been free from pain, but that swelling and soreness had also disappeared.

A striking case has been recorded by Dr. Stern, of Philadelphia, who detected a fragment of steel in the vitreous by means of the rays. Almost coincidently with the exposure there was a cessation of pain, so that the patient could both work and sleep.

M. V. Despeigne,† of Lyons, reported a case under the care of L. Voight. The patient suffered from a small epithelial cancroid nodule of the mouth. The rays were applied twice daily for periods of half, and sometimes a quarter, of an hour. The pain, which had been considerable, almost immediately ceased, so that the medical attendant was enabled to discontinue the morphine. The patient died eventually of pneumonia, but a prolonged palliative effect had followed the use of the rays.

In a previous case in his own practice, M. Despeigne found that a cancer actually decreased in volume under the influence of the focus tube. His conclusion from both cases is that, when applied to cancer, the rays have a distinct anæsthetic effect, and cause a general improvement in the condition of the patient, but exert little influence upon the growth. If this be the case, surgeons will be provided with a new anæsthetic for the relief of malignant growths far less disastrous in its general results than the evils incident to morphinism.

There have been many unfounded rumours as to the action of the Röntgen rays upon blind eyes. It seems, however, that where the optic nerve remains intact the visual sensations can be excited by the rays transmitted through media that have become opaque to ordinary light, as in cataract. The scanty nature of the evidence as to the action of the rays upon the optic nerves may be gathered from the following cases.

The case of a blind man was reported to the North-Western Electrical Association by Mr. Hoskin. The patient was unable to see the light of an arc lamp close to his face. His eyes appeared normal, but he had been completely blind for two years.

* *Boston Med. and Surg. Journal*, September 3, 1896.

† *Lyon Med. Journal*, December 28, 1896.

On being placed before a Röntgen apparatus in action, he was able to describe the general outline of the tube. A sheet of cardboard interposed cut off all visual impressions.

In this case, accepting the above statements, as Röntgen rays penetrate cardboard, any visual stimulation must have been due to some other kind of ray. If the media were not opaque, and the optic nerve insensitive both to day and to ordinary electric light, then it follows, if the rays stimulated the nerve, that there must be special nerve-endings acted upon by the rays, supposing the action to be local. Of course, it is not impossible that the rays might have penetrated the brain and stimulated the perceptive centres. In that case, however, we should expect to have had a similar phenomenon recorded from other quarters; besides, there is no reason why the figure of the tube should be fixed on the perceptive centre.

Professor Fox,* of Philadelphia, reported that a patient with corneal opacity saw nothing with an Edison's fluoroscope, whereas with the naked eye he could accurately describe the phosphorescent colour of a Crookes tube. He conjectures that Röntgen rays will not pass through cicatricial corneal tissue.

Messrs. Lortet and Genoud† have experimented on guinea-pigs with a view to ascertaining whether the tube rays had any restraining effect upon acute tuberculosis. Eight of those animals were inoculated with tubercle culture, and three submitted daily to the action of the x-rays. At the end of six weeks the latter presented considerable differences from the others that had not been so treated. Those that had undergone the exposures had no abscess at point of inoculation, the glands were well defined, and their generally good condition proved by an increase of weight. On the other hand, the inoculated guinea-pigs that had not been under the rays showed abscess at the point of inoculation, enlarged glands, and bad general condition with loss of weight.

Mr. Brunton Blaikie, of Edinburgh, found that the Röntgen rays had no visible action upon the growth of cultures of tubercle bacillus (see p. 98). He also found that guinea-pigs inoculated with diphtheria toxine, and exposed to the rays, lived actually a shorter time than those not exposed.

These experiments are worthy of further careful investigation.

* 'Ulcers of Cornea,' lecture, October 30, 1896, *Med. Bulletin*, Philadelphia.
† *La Revue Scientifique:* J. L. Breton. Paris, 1897, p. 106.
‡ *Lancet*, July 25, 1896.

D. OBSTETRICS AND GYNÆCOLOGY.

At first it was hoped that the Röntgen rays would prove of great service in obstetric medicine. In practice, however, up to the present time, experimenters have found the skiagraphy of the pregnant uterus surrounded with many difficulties. The chief obstacles are: (1) The thickness of the parts to be penetrated; (2) movements, abdominal, uterine and fœtal; (3) the difficulty of keeping a pregnant woman for any length of time in a constrained position; (4) the distance of the uterus and its contents from the sensitive plate. However, when our methods have improved, there is every hope that, with a short exposure and tubes of strong penetration, the rays will furnish obstetric physicians with an additional means of exact investigation.

The advantages of a good skiagraphic record are so obvious that they need hardly be mentioned at length. It would be possible, for instance, to ascertain the presence of twins, superfœtation, lithopædia, monstrosities, fœtal deformities, and malpresentations; while in any case pelvic deformities and exostoses could be demonstrated with ease and certainty. The demonstration of moles and of extra-uterine fœtations offers another attractive field of research.

When taken from the uterus, a good skiagram can be obtained of the fœtus, and such an illustration has been published by Dr. Oliver, by whose courtesy it is here reproduced (Fig. 57). His patient, a woman of thirty-nine, was diagnosed as having an extra-uterine fœtation, some two months beyond full term. An unsuccessful attempt was made to skiagraph the tumour in the living body. Upon operation an ovarian sac was removed containing a nine-months' fœtus, of which the accompanying excellent skiagram (Fig. 57) was made by Mr. Willoughby Smith. Dr. Oliver made the interesting observation that the ovarian sac was very opaque to the rays.

Fig. 57.—Fœtus from an Extra-Uterine Fœtation.

(Dr. Oliver's case.)

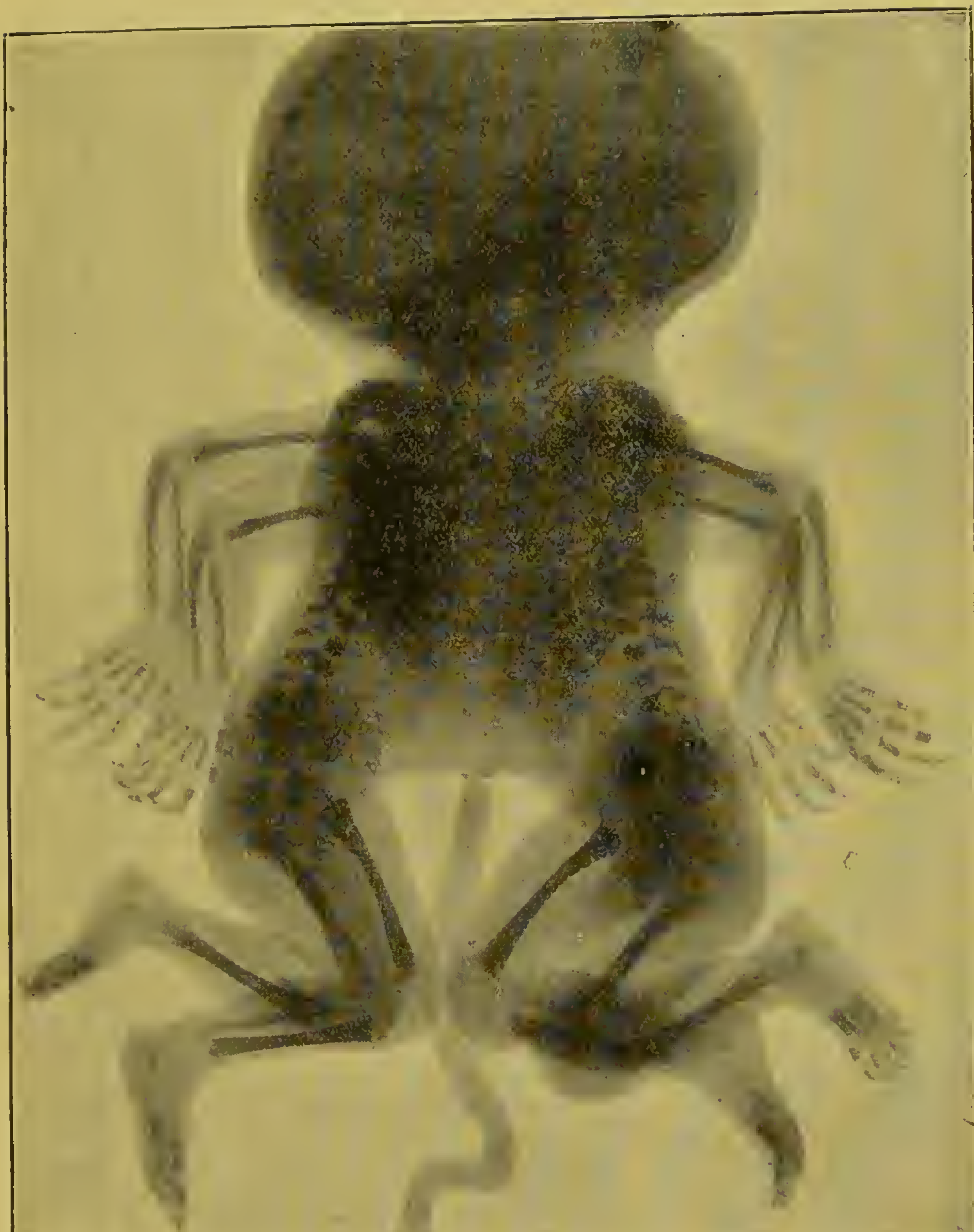


FIG. 58.—FŒTAL MONSTER.

A further important contribution to the study of fœtal skiagraphy was made by Professor Davis, of Jefferson College.* He published a skiagram which showed a faint tracing of the fœtal skull, contrasting strongly with the dark pelvis in which it had been placed. He further pointed out that the fœtal skull generally, except some portions at its base, offered little resistance to the Röntgen rays.

The same observer, however, after several unsuccessful attempts, succeeded in obtaining a faint outline of the fœtus in the living uterus. The fœtal shape could be recognised, and the position of the limbs was evident, but the head was hidden by the maternal pelvis. No fœtal skeleton could be distinguished. The experimenter concluded that the fœtal body and limbs were differentiated by the rays from the darker uterine walls and amniotic fluid.

Other observers have arrived at more or less similar results.

Messrs. Chappuis and Varnier, quoted by Dr. Mandras (Paris Thesis), made a skiagram directly after death of a guinea-pig far advanced in gestation. They obtained details of the maternal pelvis and silhouettes of four fœtuses. Negative results were obtained from a chloroformed guinea-pig.

The same experimenters showed the possibility of getting good anatomical and pathological results with the rays from the gravid uterus after removal, both when hardened in alcohol and when frozen.

Messrs. Varnier and Chappuis have obtained a Röntgen ray picture of several fœtuses in the uterus of a living guinea-pig.†

Most interesting pictures can be obtained of fœtal monstrosities, after removal from the body, by skiagraphy, which conveys anatomical information that could otherwise be obtained only by a tedious and difficult dissection. The illustration of a two-headed fœtus shown in Fig. 58 was taken from a skiagram kindly furnished for the purpose by Mr. Lynn Thomas, of Cardiff.

In the case of conjugate twins that survive and grow to maturity, such as the Siamese Twins and the Two-headed Nightingale, it is likely that the rays might afford pictures of much anatomical interest.

At the end of the year 1896, Dr. Davis summed up the position

* *American Journal of the Medical Sciences* for March, 1896.
† 'Technique des Rayons X.' A. Hébert, Paris, 1897, p. 105.

of fœtal skiagraphy as follows: 'The writer's experiments with the Röntgen rays upon pregnant women showed that it is perfectly possible to obtain an outline of the living fœtus in the body of the mother. The difficulties to be surmounted are the thickness of the tissues and the distance at which the Crookes tube is necessarily placed from the fœtus itself. Anatomical specimens of uteri and their contents, removed from the body, should occasion no difficulty whatever. By varying the electric force employed and the time of exposure, it is undoubtedly possible to obtain a useful picture of the contents of the living womb.'

GYNECOLOGY.

As methods improve, there is little doubt that valuable information will one day be obtainable, by means of the skiagraph, as to many pathological conditions of the soft tissues of the pelvis, such as ovarian tumours, fibroids, sarcomata, and various malformations.

E. LEGAL MEDICINE.

In a number of cases Röntgen ray photographs have been produced in the law-courts. The evidence they afford is corroborative, and must be taken as confirming the testimony of expert witnesses. Their special value is that exact evidence apparent to the senses of everyone concerned is rendered available by the use of unerring scientific apparatus. An ounce of such fact is worth a ton of theory obtained from roundabout deductions. To put the matter in another way, the testimony of a general practitioner armed with a corroborative skiagram would outweigh the contradictory statements of the most highly-skilled surgeon, provided the opinions of the latter were based upon nothing more tangible than the ordinary methods of physical examination. This point has been ably insisted upon by Mr. Howard Marsh* in the following passage: 'The information given by this method may be absolutely conclusive, and may directly contravene the best opinion that the most highly-qualified observer has had it in his power, under the difficult circumstances of the case, to form. With a photograph before him, any layman can see what by any other means could be only a matter of probability, balanced by other probabilities of almost equal weight.' The latter sentence describes the precise position of a juryman called upon to settle the nature of an injury in the face of conflicting skilled testimony. To such a man the skiagram would indicate a simple way out of the difficulty.

Dr. Richardson, of Boston, has quoted the following views of an American judge: 'It is the opinion of some of the judges of Massachusetts that x-ray photographs are not admissible as evidence. One judge holds that it has not been demonstrated as a scientific fact that they are accurate. The process has not

* *Brit. Med. Journal*, May 30, 1896.

become such a matter of common knowledge that the court will take judicial notice of it. No man can tell by ocular or other sensory evidence that the reproduction is accurate. The truthfulness of the photograph is a matter of reasoning.'

In considering the foregoing passage, which is a readily-understood, cautious legal attitude, it should be added that the opinion is not shared by other American judges. Broadly speaking, expert witnesses will, as a rule, be able to assume a strong position as to the absolute value of evidence derived from the Röntgen rays. Scientific evidence, it should be noted in this connection, is daily tendered and accepted in court with regard to new drugs and other medical discoveries.

The skiagraph may be valuable in any of the following medico-legal cases :

1. Evidence of injury, or of the presence of a foreign body in civil or criminal cases.
2. Evidence in action for malpraxis.
3. Evidence of bodily identification.
4. Evidence of pregnancy.
5. Evidence of age of fœtus, or of live birth.

I. EVIDENCE OF INJURY.

It is clear that the presence either of a foreign body, as a bullet, or of an injury to bone, such as a fracture, can be clearly proved by means of a skiagram. In some cases this may be taken a long time, very many years, after the original accident or injury. Thus, a fracture often leaves a lifelong and unmistakable record of its occurrence, and a dislocation may be photographed by the Röntgen rays at any time previous to its reduction.

Already numerous cases have occurred where x-ray evidence has been produced in court. One such instance was mentioned in the *British Medical Journal* for June 6, 1896, where a bullet in a hand formed the object of a criminal prosecution.

A case occurred early in 1897 in Dunfermline. A boy was accidentally shot by a rifle discharged by an unseen person at a great distance. The presence of a rifle bullet buried in the boy's lung was admirably shown by a skiagram taken by a local operator. In that case the man charged was dismissed for

want of exact identification with the person who fired the shot.

Generally speaking, in any action for injury due to negligence, if a bone be fractured or displaced, the plaintiff may obtain valuable corroborative evidence from a Röntgen photograph. Or the defendant, on the other hand, may be enabled to show thereby that the plaintiff's injury is exaggerated, misrepresented, or non-existent. As blood is opaque, the presence of a clot, if of large size and near the surface, might be detected by a skiagram.

II. EVIDENCE IN ACTION FOR MALPRAXIS.

The Röntgen rays may prove of great value to the protection of medical men, when otherwise it might be difficult to meet a charge of negligence. This point is put in a nutshell by Dr. Richardson, of Boston, who writes: 'Indeed, an early fluoroscopic examination of every fracture may be required of every surgeon for the protection of the patient, and an early photograph for the protection of the surgeon.'* At the beginning of the same year Mr. Howard Marsh advanced the statement: 'From a medico-legal point of view the Röntgen photography will clearly play a leading part in cases where surgeons are charged with having overlooked a fracture or a dislocation, when no such injury is present.'

As regards one branch of irregular or quack medical practice the new photography is likely to do yeoman's service. The bone-setters are a fraternity who batten on the ignorance and credulity of their victims. Their almost invariable plan is to tell the sufferer that a 'bone is out,' or is 'broken,' or 'has not been properly set.' Now, in all these cases Röntgen rays will reveal the exact truth of the condition. Hence it will be wise in future for everyone who consults a member of this fraternity to verify the diagnosis by an appeal to the rays before he submits to any manipulations. There is one form of fixed joint after injury, due to fibrous adhesions between the articular surfaces. In such a case the bone-setter declares the joint is dislocated, and breaks down the adhesions by a sudden wrench. Now, in such a fixation the skiagram shows the absolute absence of dislocation. On the other hand, if a clear space indicates a joint not filled

* *Boston Medical News*, December 19, 1896.

with osseous or other opaque matter (fibrous bands being transparent), then the immobility of the joint may safely be ascribed to fibrous anchylosis. Several cases of this kind, based on the negative evidence of a clear tracing of the joint space, and the positive evidence of normal relation of bones, fixed joint and previous injury, are given in the section upon bones (see p. 74).

Mr. Howard Marsh has observed of the method: 'It would have furnished valuable information to a patient met with some years ago, who had slight lateral curvature of the spine. This patient was told by a bone-setter that "his pelvis had opened, and both his hips were out." The reassurance and the mental calm which a Röntgen photograph could now bring to anyone who, having nothing seriously wrong, had been told he was the subject of such a formidable condition of things, can be easily imagined.'

It may be hoped, then, that the Röntgen rays will help to rid the world of this class of harmful social parasites. Sooner or later the strong hand of science must infallibly cut the ground away from under the feet of all such pretenders.

III. EVIDENCE OF IDENTIFICATION.

The rays may be useful in several ways in identifying both the living and the dead. For instance, they may prove the presence of former injuries, such as fractures. In the well known case of Dr. Livingstone, the African explorer, a Röntgen ray picture of the false joint in the arm due to the bite of a lion, from which injury he was known to have suffered, would have afforded valuable corroborative evidence of identification.

Another way in which the rays might be useful would be in determining the age of a body up to early adult life, from the union or non-union of bony epiphyses. Any conclusions on this point, however, would have to be formed with a due regard to the varying ages of epiphyseal union. Observations so far show that, apart from early bone disease, there is apparently a good deal of individual difference in the time of fusion of epiphyses. This point is dealt with more fully in a later section on Anatomy.

IV. EVIDENCE OF PREGNANCY.

Up to the present no very certain positive results have been obtained by the rays in the diagnosis of pregnancy—at any rate, in the living subject. It may be stated, however, that a good picture of the fœtus may be obtained *in utero* after removal from the body. Moreover, a dim outline of the fœtus has been obtained by several experimenters in the living subject. There can be little doubt, indeed, that achievements in this last-mentioned direction will before long be materially extended. One result of that particular advance would be to enable the English criminal law to replace by exact scientific methods the 'jury of matrons,' whose verdict decides whether a woman condemned to death is pregnant or otherwise. Even in these modern days, the question is on rare occasions still settled by the above-mentioned ancient tribunal.

V. EVIDENCE OF AGE OF FŒTUS.

A perfect skiagram may be obtained of a fœtus after removal from the uterus. In this way the stage of ossification can be exactly estimated, in a way that could be otherwise attained only after a tedious and difficult dissection. Moreover, by injecting the bloodvessels with a preparation of red lead, the skiagram might be made to reveal the state of the fœtal circulation.

When medico-legal evidence is required of the viability of a fœtus, however, the Röntgen ray photograph is only, as a rule, of corroborative value, inasmuch as it reveals the full-term development or otherwise. It is never likely to supersede in any way the evidence, such as the hydrostatic lung test, now accepted as to live birth. Viability, it should be remembered, is possible at seven months. The material things that may be readily demonstrated in court by means of a skiagram are fractures of the skull and other parts of the body, and the appearance of the osseous nucleus of the inferior femoral epiphysis, which Husband states, in his 'Forensic Medicine,' as a result of the examination of nine intra-uterine fœtuses at the ninth month, to have a maximum length of 2 lines. The subject of fœtal ossification is an interesting one, and no doubt the conclusions

now laid down by anatomists will be widely tested by the convenient method of skiagraphy.

Positive skiagraphic evidence, however, as to the fact of separate existence of a child has been suggested by M. Bordas.* On June 8, 1896, he laid before the Paris Société de Médecine Légale two skiagrams of fœtal lungs which showed the presence of air-bubbles in the lungs of those who had breathed, as against absolute opacity in the same region of the still-born.

It has been proposed to apply the rays as a test of death, but hitherto it has not been found possible to carry out the suggestion in practice.

* 'Technique des Rayons X.' A. Hébert, Paris, 1897, p. 105.

F. ANATOMY.

A good deal of light has been already acquired in relation to the age at which union of bony epiphyses takes place. It seems likely, in view of the facts afforded by Röntgen ray researches, that much of the information upon this point contained in the anatomical text-books will have to be rewritten. It appears certain, for instance, that the variation of the individual in this matter is much wider than hitherto recognised by the anatomists. The new method offers obvious advantages in obtaining data for general conclusions as to ages of ossific union. Supposing, for instance, it be desired to study the epiphyses of the humerus at the age of fourteen. A sufficient number of skiagrams of the humerus of persons of that age—carefully verified, it need hardly be said—would have to be procured, and the results compared at leisure. This method would be rapid and accurate as compared with the tedious and more or less uncertain observations to be gleaned from the alternative plan of many laborious dissections. Moreover, the rays could be applied to the living as well as to the dead, and also to bodies where post-mortem examination would be impossible.

ANATOMY OF BLOODVESSELS.

The injection of bloodvessels by some material opaque to the rays, and then subjecting them to skiagraphy, opens up a wide field of anatomical investigation. In this way Dr. F. J. Clendinnen, of Melbourne,* demonstrated the arteries of a seven-month fœtus, which he had injected with a solution of red lead. That particular salt was used because, as the result of previous experi-

* *Internat. Med. Journal of Australasia*, October 20, 1896, p. 611.

ments, he had come to the conclusion that red was more opaque than other colours. His skiagraph affords a sharp and beautiful diagrammatic view of the arteries, even where they pass behind the fœtal bones. A peculiarity such as that of double high division of the brachial artery is well shown.

In a later issue of the same journal (January 20, 1897), Dr. Clendinnen published some beautiful skiagrams obtained in a similar way. They showed the arteries about the knee and the ankle-joint. The small muscular twigs and other minute branches are reproduced with the utmost fidelity. The larger vessels are distinctly visible, even when they pass behind bone, a tissue much less opaque than lead to the rays.

There can be no doubt that this method may now and then afford a valuable means of showing in a graphic manner the facts of local blood-supply, both in normal and in pathological specimens. As an instance of the latter, a very perfect picture could be obtained of circulation by anastomoses, say, in a case where during life the femoral artery had been tied for aneurism.

Dr. Clendinnen adds that in one case he obtained from the living body a good skiagram of the popliteal artery. This observation is most valuable, and points to the time when a fuller knowledge of conditions in relation to results will bring the blood-vessels under command of the skiagrapher.

Messrs. Rémy and Contremoulins have made similar observations by injecting the arteries with a solution of wax in alcohol charged with various metallic powders.

Dr. Nathan Raw showed to the Manchester Pathological Society, in December, 1896, skiagrams of arteries injected with plaster of Paris and carmine.

Another application of this principle of opaque injection was brought forward by Poncet, of Lyons.* He presented the Academy of the town mentioned with a series of skiagrams by Destot and Bérard, showing the arterial and venous circulation of the kidney in various pathological conditions of that organ.

Some of the interesting conclusions as to the normal vascular conditions may be quoted. Thus, it was found that the circulation in the kidney is lobar and terminal, and permits the differentiation of an independent anterior and posterior kidney, except the artery

* *Gazette des Hôpitaux*, December 31, 1896.

of the superior lobe, which often divides into two branches, so that, when it is injected, the entire upper portion is permeated.

The bearing of researches of this nature upon the study of the evolution of organs is obvious.

Another field in normal anatomy is the relation of parts in the body. The exact relation of the bladder and urethra, for instance, might be studied by filling the organ and passages with melted paraffin, holding in solution some opaque mineral substance, as zinc or lead oxide.

In pathological anatomy, it is possible that not a few points of interest might be solved by injecting the hollow viscera with opaque solutions, and then skiagraphing the result.

G. PHYSIOLOGY.

Interesting results have been obtained by Messrs. Hébert and Bertin-Sans from the skiagraphy of the movements of joints, more especially in the case of the wrists. Their observations will no doubt be sooner or later considerably extended.

A number of interesting observations have already been made upon the movements of the heart.

Wherever in the interior of the body there is pulsation in any organ open to skiagraphy, the process of chrono-photography will be available. The possible presentation of a pulsating human heart upon a lantern screen, by a method so young that it is yet barely articulate, speaks volumes for the energy of latter-day science.

Professor Benedikt, of Vienna, has found that movements of the heart are best studied in young or emaciated subjects. He noted during cardiac systole a shortening between apex and base, and concluded there was only a systolic lateral apex impulse. Further, during systole the heart is not entirely emptied of blood, for a shadow cast by residual blood is recognisable. The bloodless heart is relatively transparent, but even thin layers of blood cast a shadow.

MM. Sabrazès and Rivière recently announced to the Paris Academy of Science that the rays had no influence either upon the action of white blood corpuscles, or upon the phenomena of phagocytosis, while a frog's heart exposed to the rays for several hours appeared to undergo no alteration in movement.*

* *Lancet*, May 29, 1897, p. 1505.

H. THE RAYS IN VETERINARY SURGERY.

A GOOD deal of work has been done with the Röntgen rays in veterinary practice by Professor Hobday, of the London Veterinary College, and others.

The horse's hoof he found to be readily penetrable by the rays, so that a foreign metallic body, such as a misdirected nail, could be at once detected in that region. In conjunction with Mr. Sydney Rowland he obtained several skiagrams of cats suffering from various accidents. In the *Veterinarian* for September, 1896, Professor Hobday and Mr. Johnson wrote: 'In conclusion, the authors consider that the Röntgen rays can be successfully applied to the smaller animals without much difficulty. In the horse, the mechanical difficulties of restraint have been successfully overcome. . . . For diagnosis of abnormalities of the bones of the limbs, such as suspected fracture of the pastern, small ringbone, sidebone, or foreign body in the hoof, the results demonstrate that this method can be applied successfully. With the bones of the neck, too, no great difficulty is anticipated.'

Since that time much more has been accomplished. Those who are interested in the subject will find numerous articles in the various journals devoted to veterinary science.

APPENDIX.

A NEW FORM OF RADIATION.

BEING A PRELIMINARY COMMUNICATION TO THE WÜRTZBURG PHYSICO-MEDICAL SOCIETY, BY PROFESSOR WILHELM KONRAD RÖNTGEN, DECEMBER, 1895.

1. IF we pass the discharge from a large Ruhmkorff coil through a Hittorf or a sufficiently exhausted Lenard, Crookes, or similar apparatus, and cover the tube with a somewhat closely-fitting mantle of thin black cardboard, we observe in a completely-darkened room that a paper screen washed with barium-platino-cyanide lights up brilliantly and fluoresces equally well whether the treated side or the other be turned towards the discharge-tube. Fluorescence is still observable 2 metres away from the apparatus. It is easy to convince one's self that the cause of the fluorescence is the discharge from the apparatus, and nothing else.

2. The most striking feature of this phenomenon is that an influence capable of exciting brilliant fluorescence is able to pass through the black cardboard cover, which transmits none of the ultra-violet rays of the sun or of the electric arc, and one immediately inquires whether other bodies possess this property. It is soon discovered that all bodies are transparent to this influence, but in very different degrees. A few examples will suffice. Paper is very transparent;* the fluorescent screen still lighted up brightly when held behind a bound volume of 1,000 pages; the printer's ink offered no perceptible obstacle. Fluorescence was also noted behind two packs of cards; a few cards held between tube and screen made no perceptible difference. A single sheet of tinfoil is scarcely noticeable; only after several layers have been laid on top of each other is a shadow clearly visible on the screen. Thick blocks of wood are also transparent; fir-planks from 2 cm. to 3 cm. thick are but slightly opaque. A film of aluminium about 15 mm. thick weakens the effect considerably, though it does not entirely destroy the fluorescence. Several centimetres of vulcanized indiarubber let the rays through.† Glass plates of the same thick-

* By the 'transparency' of a body I denote the ratio of the brightness of a fluorescent screen held right behind the body in question to the brightness of the same screen under exactly the same conditions, but without the interposing body.

† For brevity's sake I should like to use the expression 'rays,' and to distinguish these from other rays I will call them 'x-rays.'

ness behave in a different way, according as they contain lead (flint glass) or not; the former are much less transparent than the latter. If the hand be held between the tube and the screen, the dark shadow of the bones is visible within the slightly dark shadow of the hand. Water, bisulphide of carbon and various other liquids behave in this respect as if they were transparent. I was not able to determine whether water was more transparent than air. Behind plates of copper, silver, lead, gold, platinum, fluorescence is still clearly visible, but only when the plates are not too thick. Platinum 0·2 mm. thick is transparent; silver and copper sheets may be decidedly thicker. Lead 1·5 mm. thiek is practically opaque, and was on this account often made use of. A wooden rod of 20 by 20 mm. cross-section, painted with white lead paint on one side, behaves in a peculiar manner. When it is interposed between apparatus and screen it has almost no effect when the x-rays go through the rod parallel to the painted side, but it throws a dark shadow if the rays have to traverse the paint. Very similar to the metals themselves are their salts, whether solid or in solution.

3. These and other experimental results led to the conclusion that the transparency of different substances of the same thickness is mainly conditioned by their density; no other property is in the least comparable with this.

The following experiments, however, show that density is not altogether alone in its influence. I experimented on the transparency of nearly the same thickness of glass, aluminium, calcspar and quartz. The density of these substances is nearly the same, and yet it was quite evident that the spar was decidedly less transparent than the other bodies, which were very much like each other in their behaviour. I have not observed calcspar fluoresce in a manner comparable with glass.

4. With increasing thickness all bodies become less transparent. In order to find a law connecting transparency with thickness, I made some photographic observations, the photographic plate being partly covered with an increasing number of sheets of tinfoil. Photometric measurements will be undertaken when I am in possession of a suitable photometer.

5. Sheets of platinum, lead, zinc, and aluminium were rolled until they appeared to be of almost equal transparency. The following table gives the thicknesses in millimetres, the thicknesses relative to the platinum sheet and the density:

Thickness.	*Relative Thickness.*	*Density.*
Pt 0·018	1	21·5
Pb 0·05	3	11·3
Zn 0·10	6	7·1
Al 3·5	200	2·6

It is to be observed in connection with these figures that, although the product of the thickness into the density may be the same, it does not in any way follow that the transparency of the different metals is the same. The transparency increases at a greater rate than this product decreases.

6. The fluorescence of barium-platino-cyanide is not the only recognisable phenomenon due to x-rays. It may be observed, first of all, that other bodies fluoresce—for example, phosphorus, calcium compounds, uranium glass, ordinary glass, calcspar, rock salt, etc.

Of especial interest in many ways is the fact that photographic dry plates show themselves susceptible to x-rays. We are thus in a position to corroborate many phenomena in which mistakes are easy, and I have, whenever possible, controlled each important ocular observation on fluorescence by means of photography. Owing to the property possessed by the rays of passing almost without any absorption through thin sheets of wood, paper, or tinfoil, we can take the impressions on the photographic plate inside the camera or paper cover whilst in a well-lit room. In former days this property of the ray only showed itself in the necessity under which we lay of not keeping undeveloped plates, wrapped in the usual paper and board, for any length of time in the vicinity of discharge-tubes. It is still open to question whether the chemical effect on the silver salts of photographic plates is exercised directly by the x-rays. It is possible that this effect is due to the fluorescent light which, as mentioned above, may be generated on the glass plate, or perhaps on the layer of gelatine. 'Films' may be used just as well as glass plates.

I have not as yet experimentally proved that the x-rays are able to cause thermal effects, but we may very well take their existence as probable, since it is proved that the fluorescent phenomenon alters the properties of x-rays, and it is certain that all the incident x-rays do not leave the bodies as such.

The retina of the eye is not susceptible to these rays. An eye brought close up to the discharge apparatus perceives nothing, although, according to experiments made, the media contained in the eye are fairly transparent.

7. As soon as I had determined the transparency of different substances of various thicknesses, I hastened to ascertain how the x-rays behaved when passing through a prism—whether they were refracted or no. Water and carbon disulphide, in prisms of about 30° refractive angle, showed neither with the fluorescing screen nor with the photographic plate any sign of refraction. For purposes of comparison the refraction of light rays was observed under the same conditions; the refracted images on the plate were respectively about 10 mm. and 20 mm. from the non-refracted one. With an aluminium and a vulcanized rubber prism of 30° angle I have obtained images on photographic plates in which one may perhaps see refraction. But the matter is very uncertain, and even if refraction exists, it is so small that the refractive index of the x-ray for the above materials can only be, at the highest, 1·05. Using the fluorescent screen, I was unable to discover any refraction at all in the case of the aluminium and the rubber prism.

Researches with prisms of denser metals have yielded up to now no certain results, on account of the small transparency, and consequently lessened intensity, of the transmitted ray.

In view of this state of things, and the importance of the question whether x-rays are refracted on passing from one medium to another, it is satisfactory to find that this question can be attacked in another way than by means of prisms. Finely-powdered substances in sufficient thicknesses allow only a very little of the incident light to pass through, and that is dispersed by refraction and reflection. Now, powdered substances are quite as transparent to x-rays as are solid bodies of equal mass. Hence, it is proved that refraction and regular reflection do not exist to a noticeable degree. The experiments were carried out with finely-powdered rock salt, with powdered electrolytic silver, and with the zinc powder much used in chemical work. In no case was any difference observed between the transparency of the powdered and solid substance, either when using the fluorescent screen or the photographic plate.

It follows, from what has been said, that the x-rays cannot be concentrated by lenses; a large vulcanized rubber and glass lens were without influence. The shadow of a round rod is darker in the middle than at the edge; that of a tube filled with any substance more transparent than the material of the tube is lighter in the middle than at the edge.

8. The question of the reflection of the x-rays is settled in one's mind by the preceding paragraphs, and no appreciable regular reflection of the rays from the substances experimented with need be looked for. Other investigations, which I will describe here, lead to the same result. Nevertheless, an observation must be mentioned which at first sight appears to contradict the above statement. I exposed a photographic plate to the x-rays, protected against light rays by black paper, the glass side being directed toward the discharge-tube. The sensitive layer was nearly covered, star fashion, with blanks of platinum, lead, zinc, and aluminium. On developing the negative, it was clearly noticeable that the blackening under the platinum, lead, and especially under the zinc, was greater than in other places. The aluminium had exercised hardly any effect. It appeared, therefore, that the three above-mentioned metals had reflected the rays. Nevertheless, other causes for the greater blackening were thinkable, and in order to make sure I made a second experiment, and laid a piece of thin aluminium, which is opaque to ultra-violet rays, though very transparent to x-rays, between the sensitive layers and the metal blanks. As again much the same result was found, a reflection of x-rays by the above-mentioned metals was demonstrated. But if we connect these facts with the observation that powders are quite as transparent as solid bodies, and that, moreover, bodies with rough surfaces are, in regard to the transmission of x-rays, as well as in the experiment just described, the same as polished bodies, one comes to the conclusion that regular reflection, as already stated, does not exist, but that the bodies behaved to the x-rays as muddy media do to light.

Again, as I could discover no refraction at the point of passage from one

medium to another, it would seem as if the x-rays went through all substances at the same speed, and that in a medium which is everywhere, and in which the material particles are embedded, the particles obstruct the propagation of the x-rays in proportion to the density of the bodies.

9. Hence it may be that the arrangement of the particles in the bodies influences the transparency; that, for example, equal thicknesses of calcspar would exhibit different transparencies, according as the rays were in the direction of the axis or at right angles to it. Researches with calcspar and quartz have yielded a negative result.

10. It is well known that Lenard, in his beautiful investigation on Hittorf cathode rays passed through thin aluminium-foil, came to the conclusion that these rays were actions in the ether, and that they pass diffusively through all bodies. I have been able to say the same about my rays.

In his last work Lenard has determined the absorption coefficient of various bodies for cathode rays, and among other things for air atmospheric pressure at 4·1, 3·4, 3·1, per centimetre, and found it connected with the exhaustion of the gas contained in the discharge apparatus. In order to estimate the discharge pressure by the spark-gap method, I used in my researches almost always the same exhaustion. I succeeded with a Weber photometer (I do not possess a better one) in comparing the intensity of the light of my fluorescing screen at distances of about 100 mm. and 200 mm. from the discharge apparatus, and found in the case of three tests agreeing well with one another, that it varied very nearly inversely at the square of the distance of the screen from the discharge apparatus. Hence the air absorbs a very much smaller fraction of the x-rays than of the cathode rays. This result is also quite in agreement with the result previously mentioned, that the fluorescing light was still observable at a distance of 2 metres from the discharge-tube.

Other bodies behave generally like air—that is to say, they are more transparent for x-rays than for cathode rays.

11. A further noteworthy difference in the behaviour of cathode rays and x-rays consists in the fact that, in spite of many attempts, I have not succeeded, even with very strong magnetic fields, in deflecting x-rays by a magnet. The magnetic deflection has been, up to now, a characteristic mark of the cathode ray; it was, indeed, noticed by Hertz and Lenard that there were different kinds of cathode rays, 'distinguishable from one another by their phosphorescing powers, absorption and magnetic deflection,' but a considerable deflection was nevertheless observed in all cases, and I do not think this characteristic will be given up without overwhelming evidence.

12. After experiments bearing specially on this question, it is certain that the spot on the wall of the discharge apparatus which fluoresces most decidedly must be regarded as the principal point of the radiation of the x-rays in all directions. The x-rays thus start from the point at which, according to the researches of different investigators, the cathode rays impinge upon the wall of the glass tube. If one deflects the cathode rays

within the apparatus by a magnet, it is found that the x-rays are emitted from another spot—that is to say, from the new termination of the cathode stream.

On this account, also, the x-rays, which are not deflected, cannot merely be unaltered reflected cathode rays passing through the glass wall. The greater density of the glass outside the discharge-tube cannot, according to Lenard, be made responsible for the great difference in the 'deflectability.'

I therefore come to the conclusion that the x-rays are not identical with the cathode rays, but that they are generated by the cathode rays at the glass wall of the discharge apparatus.

13. This excitation does not take place only in glass, but also in aluminium, as I was able to ascertain with an apparatus closed by a sheet of aluminium 2 mm. thick. Other substances will be studied later on.

14. The justification for giving the name of 'rays' to the influence emanating from the wall of the discharge apparatus depends partly on the very regular shadows which they form when one interposes more or less transparent bodies between the apparatus and the fluorescing screen or photographic plate. Many such shadow-pictures, the formation of which possesses a special charm, have I observed—some photographically. For example, I possess photographs of the shadow of the profile of the door separating the room in which was the discharge apparatus from the room in which was the photographic plate; also photographs of the shadows of the bones of the hand, of the shadow of a wire wound on a wooden spool, of a weight inclosed in a small box, of a compass in which the magnetic needle is completely surrounded by metal, of a piece of metal the lack of homogeneity of which was brought out by the x-rays, etc.

To show the rectilinear propagation of the x-rays there is a pinhole photograph, which I was able to take by means of the discharge apparatus covered with black paper. The image is weak, but unmistakably correct.

15. I looked very carefully for interference phenomena with x-rays, but unfortunately, perhaps on account of the small intensity of the rays, without success.

16. Researches to determine whether electrostatic forces affect x-rays in any way have been begun, but are not completed.

17. If we ask what x-rays—which certainly cannot be cathode rays—really are, we are led at first sight, owing to their powerful fluorescing and chemical properties, to think of ultra-violet light. But we immediately encounter serious objections. If x-rays be in reality ultra-violet light, this light must possess the following characteristics:

(*a*) It must show no perceptible refraction on passing from air into water, bisulphide of carbon, aluminium, rock salt, glass, zinc, etc.

(*b*) It must not be regularly reflected to any appreciable extent from the above bodies.

(*c*) It must not be polarizable by the usual means.

(*d*) Its absorption must not be influenced by any of the properties of substances to the same extent as it is by their density.

In other words, we must assume that these ultra-violet rays behave in quite a different manner from any infra-red, visible, or ultra-violet rays hitherto known. I could not bring myself to this conclusion, and I have, therefore, sought another explanation.

There seems at least some connection between the new rays and light rays in the shadow-pictures and in the fluorescing and chemical activity of both kinds of rays. Now, it has been long known that, besides the transverse light vibrations, longitudinal vibrations might take place in the ether, and, according to the view of different physicists, must take place. Certainly their existence has not up till now been made evident, and their properties have not, on that account, been experimentally investigated.

May not the new rays be due to longitudinal vibrations in the ether?

I must admit that I have put more and more faith in this idea in the course of my research, and I therefore advance that surmise, although I know that such an explanation requires further corroboration.

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